

Association Between Body Mass Index and Mortality in Chinese Older Adults: A Cohort Study Postprint

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Abstract

Background Obesity is an important public health issue, and overweight and obesity are risk factors for multiple chronic diseases. However, the “obesity paradox” proposed in recent years has attracted widespread attention, and the relationship between BMI and mortality in the elderly remains unclear.

Objective To analyze the effect of BMI on mortality risk in Chinese elderly.

Methods General data, laboratory examinations, and follow-up data were collected from elderly individuals aged ≥ 60 years who underwent health examinations at the Healthcare Center of Beijing Friendship Hospital, Capital Medical University from April to December 2015. Follow-up was completed from March to April 2024, with endpoint event follow-up adopted and the follow-up deadline being April 30, 2024. The primary endpoint event was all-cause mortality, and the secondary endpoint event was cardiovascular event-related mortality. Multivariate Cox proportional hazards regression model was used to analyze the association between BMI and mortality risk in the elderly.

Results A total of 599 elderly individuals were included, with 477 males (79.6%) and a mean age of (77 ± 8) years. According to BMI, they were divided into underweight group (18 cases, 3.0%), normal weight group (221 cases, 36.9%), overweight group (273 cases, 45.6%), and obesity group (87 cases, 14.5%). The median follow-up time was 8.81 years. By the end of follow-up, 158 cases (26.4%) had died. Restricted cubic spline plots showed a U-shaped curve between BMI and mortality risk. Multivariate Cox proportional hazards regression analysis results showed that after adjusting for variables such as age, gender, and underlying diseases, compared with normal weight, underweight elderly had increased all-cause mortality risk (HR=2.76, 95%CI=1.37~5.55). Additionally, low BMI was an independent risk factor for cardiovascular event-related mortality in the

elderly (HR=5.55, 95%CI=1.83~16.78). No effect of overweight or obesity on mortality was observed ($P>0.05$).

Conclusion The relationship between BMI and mortality presents a U-shaped curve. Underweight is an independent risk factor for all-cause mortality and cardiovascular event-related mortality in the elderly. No increased mortality risk was found for overweight/obesity in the elderly, and weight management in the elderly should be emphasized.

Full Text

Association between Body Mass Index and Mortality among Older Chinese: A Cohort Study

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Abstract

Background: Obesity represents a significant public health challenge, as both obesity and overweight constitute risk factors for numerous chronic diseases. However, the “obesity paradox” proposed in recent years has attracted widespread attention, and the relationship between Body Mass Index (BMI) and mortality in the elderly remains unclear. **Objective:** To analyze the impact of BMI on mortality risk among older adults in China.

Methods: This retrospective cohort study recruited elderly individuals aged 60 years and older who underwent routine health examinations at the Healthcare Center of Beijing Friendship Hospital, Capital Medical University, between April and December 2015. Follow-up was completed between March and April 2024 using endpoint event tracking, with a cutoff date of April 30, 2024. The primary endpoint was all-cause mortality, and the secondary endpoint was cardiovascular disease-related mortality. Multivariable Cox proportional hazards regression models were used to examine the association between BMI and mortality risk.

Results: A total of 599 elderly participants were included, with 477 men (79.6%) and a mean age of (77 \pm 8) years. According to BMI classification, 18 subjects (3.0%) were underweight, 221 (36.9%) had normal weight, 273 (45.6%)

were overweight, and 87 (14.5%) were obese. The median follow-up duration was 8.81 years, during which 158 participants (26.4%) died. Restricted cubic spline analysis revealed a U-shaped relationship between BMI and mortality risk. Multivariable Cox proportional hazards regression analysis showed that, after adjusting for age, sex, and comorbidities, underweight elderly individuals had an elevated risk of all-cause mortality compared to those with normal weight (HR=2.76, 95%CI=1.37-5.55). Furthermore, low BMI was an independent risk factor for cardiovascular mortality (HR=5.55, 95%CI=1.83-16.78). No significant association was observed between overweight/obesity and mortality ($P>0.05$).

Conclusion: The relationship between BMI and mortality follows a U-shaped curve, with underweight being an independent risk factor for both all-cause and cardiovascular mortality in the elderly. No increased mortality risk was found for overweight or obese elderly individuals. These findings underscore the importance of weight management in older adults.

Keywords: Obesity; Aged; Body Mass Index; Obesity Paradox; Mortality Risk; Cox Regression

Introduction

With continuous improvements in living standards, the prevalence of obesity has been rising steadily. Based on BMI calculations, global obesity rates have reached pandemic levels. In the United States, obesity prevalence reached 42.4% in 2018. As the world's most populous nation, China has experienced a three-fold increase in obesity rates over the past 15 years. Statistics indicate that approximately 85 million Chinese adults aged 18-69 were obese in 2018, making China one of the countries with the largest number of overweight and obese individuals worldwide.

As population aging intensifies, overweight and obesity have become increasingly prominent issues among older adults. Research shows that significant changes in body composition occur during aging, characterized primarily by decreased muscle mass and increased fat mass. Consequently, approximately one-third of older adults are classified as obese, with this proportion continuing to rise. In 2015, an estimated 4 million deaths globally were attributed to high BMI, drawing widespread attention to this issue. Multiple studies have demonstrated that overweight and obesity are closely associated with all-cause mortality. Moreover, obesity is an independent risk factor for diabetes, cardiovascular disease, cerebrovascular disease, and other chronic conditions, imposing a heavy burden on global public health.

However, recent studies have found that among cardiovascular disease patients, those who are overweight or obese have lower all-cause and cardiovascular mortality rates compared to those with normal weight. This phenomenon, where

obesity exhibits diametrically opposite effects in health and disease contexts, is termed the “obesity paradox.” The mechanisms underlying this paradox in cardiovascular disease patients remain complex and not fully elucidated, with hypotheses primarily involving metabolic burden, cachexia incidence, atrial natriuretic peptide levels, renin-angiotensin-aldosterone system activity, and cardiorespiratory fitness levels. Current research on the association between BMI and adverse outcomes has focused mainly on healthy younger populations, consistently showing a U- or J-shaped relationship where the lowest mortality occurs within the healthy weight range (20–25 kg/m²). With advancing age, significant metabolic changes occur in the musculoskeletal system of older adults, with decreased muscle mass accompanied by redistributed and increased body fat. Although obesity is a risk factor for multiple chronic diseases, a prospective cohort study of individuals aged 80 years and older found that higher BMI was associated with lower mortality risk. The potential protective effects of overweight and obesity on health in older adults require further investigation, and whether the “obesity paradox” serves as a protective factor for health and survival in the elderly population remains unclear.

This uncertainty has sparked widespread debate regarding the relationship between obesity and mortality in older adults, the definition of obesity in this population, and whether intervention is necessary. Therefore, this study aims to explore the association between BMI and mortality in older adults, clarify the health impacts of overweight and obesity, and provide scientific evidence for weight management in this population.

Methods

Study Design and Participants

This retrospective cohort study selected older adults who underwent routine health examinations at the Healthcare Center of Beijing Friendship Hospital, Capital Medical University, between April and December 2015. Follow-up was completed between March and April 2024. Inclusion criteria were: (1) age \geq 60 years; (2) signed informed consent. Exclusion criteria were: (1) incomplete clinical data or laboratory results; (2) malignant tumors or life expectancy $<$ 3 months; (3) refusal to participate in follow-up. This study was approved by the Ethics Committee of Beijing Friendship Hospital, Capital Medical University (Ethics Approval No.: 2023-P2-303-02).

Data Collection

General Information: Demographic data were collected, including sex, age, BMI, systolic and diastolic blood pressure, and comorbidities (hypertension, diabetes, coronary heart disease, hyperlipidemia, cerebrovascular disease, chronic lung disease [chronic bronchitis, chronic obstructive pulmonary disease], and malignant tumors).

Laboratory Tests: Laboratory results were collected, including red blood cell count, hemoglobin, glycated hemoglobin, transaminases, creatinine, urea nitrogen, triglycerides, high-density lipoprotein, low-density lipoprotein, and uric acid.

Follow-up Data: Follow-up was conducted via telephone and review of medical records using endpoint event tracking, with a cutoff date of April 30, 2024. The primary endpoint was all-cause mortality, and the secondary endpoint was cardiovascular disease-related mortality.

Diagnostic Criteria: BMI classification followed Chinese standards: underweight < 18.5 kg/m², normal weight 18.5–23.9 kg/m², overweight 24.0–27.9 kg/m², and obesity ≥ 28 kg/m².

Statistical Analysis

Statistical analysis was performed using SPSS 26.0 and R 4.3.0 software. Normally distributed continuous variables were expressed as mean \pm standard deviation, with intergroup comparisons using ANOVA and post-hoc comparisons using the LSD method. Non-normally distributed continuous variables were expressed as median (P25, P75) and compared using non-parametric tests. Categorical variables were expressed as frequencies and compared using χ^2 tests. Univariate and multivariate Cox proportional hazards regression analyses were used to examine the association between BMI and mortality. Variance inflation factor (VIF) testing was used to assess multicollinearity; variables with $VIF \geq 5$ were considered to have significant collinearity and were removed from the multivariate model. Subgroup analyses were conducted based on comorbidities to further clarify the effect of BMI on mortality. A P-value < 0.05 was considered statistically significant.

Results

Baseline Characteristics

A total of 599 older adults were included, with a mean age of (77 \pm 8) years, of which 39.1% (234 cases) were aged 80 years or older. The cohort comprised 477 men (79.6%) and 122 women (20.4%). Comorbidities included hypertension (305 cases, 50.9%), diabetes (116 cases, 19.4%), hyperlipidemia (285 cases, 47.6%), coronary heart disease (199 cases, 33.2%), cerebrovascular disease (123 cases, 20.5%), chronic lung disease (131 cases, 21.9%), and malignant tumors (106 cases, 17.7%). Based on BMI classification, participants were divided into underweight (18 cases, 3.0%), normal weight (221 cases, 36.9%), overweight (273 cases, 45.6%), and obese (87 cases, 14.5%) groups. The median follow-up duration was 8.81 years, during which 158 participants (26.4%) died, with the top three causes of death being pneumonia (93 cases), cardiovascular events (44 cases), and malignant tumors (21 cases).

Comparison Among BMI Groups

Significant differences were observed among the four BMI groups in sex distribution, white blood cell count, hemoglobin, alanine aminotransferase, glycated hemoglobin, fasting glucose, total cholesterol, triglycerides, high-density lipoprotein, serum creatinine, uric acid, and comorbidities (hypertension, hyperlipidemia, and malignant tumors) ($P < 0.05$). No significant differences were found in age, systolic blood pressure, diastolic blood pressure, albumin, aspartate aminotransferase, low-density lipoprotein, urea nitrogen, cystatin C, diabetes, coronary heart disease, cerebrovascular disease, or chronic lung disease ($P > 0.05$).

Cox Proportional Hazards Regression Analysis

Restricted cubic spline (RCS) curves revealed a non-linear, U-shaped relationship between BMI and mortality risk, which persisted after adjusting for age, sex, and comorbidities [Figure 1: see original paper]. Using all-cause mortality and cardiovascular mortality as dependent variables (yes=0, no=1), and sex (male=1, female=2), BMI group (normal weight=1, underweight=2, overweight=3, obese=4), hypertension (yes=0, no=1), diabetes (yes=0, no=1), hyperlipidemia (yes=0, no=1), coronary heart disease (yes=0, no=1), cerebrovascular disease (yes=0, no=1), chronic lung disease (yes=0, no=1), malignant tumors (yes=0, no=1), and continuous variables including age, BMI, systolic blood pressure, diastolic blood pressure, white blood cells, hemoglobin, alanine aminotransferase, aspartate aminotransferase, glycated hemoglobin, glucose, total cholesterol, triglycerides, high-density lipoprotein, low-density lipoprotein as independent variables, univariate and multivariate Cox regression analyses were performed. Univariate analysis showed that age, systolic blood pressure, diastolic blood pressure, white blood cells, hemoglobin, albumin, alanine aminotransferase, glycated hemoglobin, fasting glucose, urea nitrogen, creatinine, and BMI were associated with all-cause and cardiovascular mortality ($P < 0.05$).

VIF testing was used to assess multicollinearity severity. After converting categorical variables to dummy variables, total cholesterol and low-density lipoprotein showed severe multicollinearity (VIF=20.73 and 16.52, respectively) and were excluded from the multivariate Cox regression model. After adjusting for age, sex, hemoglobin, glucose, and other covariates, underweight individuals (BMI < 18.5 kg/m²) had a higher risk of all-cause mortality compared to the normal weight group (HR=2.97, 95%CI=1.56-5.66). This elevated risk remained significant after further adjustment for hypertension, diabetes, coronary heart disease, hyperlipidemia, cerebrovascular disease, chronic lung disease, and malignant tumors (HR=2.76, 95%CI=1.37-5.55). No increased mortality risk was observed in the overweight or obese groups.

For the secondary endpoint of cardiovascular mortality, Cox proportional hazards models showed that underweight individuals had a 4.55-fold higher risk of cardiovascular death compared to normal weight individuals (HR=4.55,

95%CI=1.83-16.78), independent of age, sex, and comorbidities .

Subgroup Analysis

To further clarify the effect of BMI on mortality risk across different sex, age, and disease subgroups, stratified analyses were performed. Among the 365 participants aged 60-79 years (60.9%) and 234 participants aged ≥ 80 years (39.1%), low BMI significantly increased all-cause mortality risk in women and in patients without hypertension, diabetes, cerebrovascular disease, chronic lung disease, or malignant tumors ($P < 0.05$). The presence of coronary heart disease or hyperlipidemia did not modify the effect of BMI on all-cause mortality, with low BMI remaining an independent risk factor regardless of these conditions [Figure 2: see original paper].

For the secondary endpoint of cardiovascular mortality, low BMI significantly increased cardiovascular death risk in participants aged ≥ 80 years without chronic comorbidities (including hypertension, diabetes, coronary heart disease, hyperlipidemia, cerebrovascular disease, and chronic lung disease) ($P < 0.05$). This effect was independent of malignant tumor status [Figure 3: see original paper].

Discussion

Weight management is a crucial component of health management; however, consensus on the optimal BMI range for older adults has not been reached and requires further investigation. With aging, muscle mass decreases and the prevalence of sarcopenia increases. Additionally, sarcopenic obesity, characterized by concurrent sarcopenia and obesity, has emerged as a concern in older populations. This study found that low BMI ($< 18.5 \text{ kg/m}^2$) is an independent risk factor for all-cause mortality in older adults, with the low BMI group having 2.33 times higher mortality risk than the normal BMI group. Furthermore, low BMI increased the risk of cardiovascular mortality ($\text{HR} = 5.55$), while no increased risk was observed for overweight or obese individuals. The RCS curves demonstrated a U-shaped relationship between BMI and all-cause mortality.

The relationship between BMI and mortality risk in older adults shows considerable variation across studies. A meta-analysis of 12 studies found that among patients with peripheral artery disease, underweight individuals had significantly higher mortality risk ($\text{HR} = 1.72$, 95%CI=1.38-2.14) compared to normal weight patients, while obese patients had reduced mortality ($\text{HR} = 0.78$, 95%CI=0.62-0.97). Another meta-analysis of 32 studies including 197,940 older adults with a mean follow-up of 12 years, using BMI 23.0-23.9 kg/m^2 as the reference, found that BMI 21.0-21.9 kg/m^2 and 20.0-20.9 kg/m^2 were associated with 12% and 19% increased mortality risk, respectively. Notably, this study showed that overweight did not increase mortality risk, with increased risk only observed when

BMI exceeded 33.0 kg/m² (HR=1.08, 95%CI=1.00-1.15), while low BMI significantly increased mortality risk in older adults. A study of post-cholecystectomy patients (n=327,473) found that underweight patients had increased mortality and rehospitalization rates compared to normal weight patients, while obese patients had higher rates of wound infection and dehiscence and longer operative times, suggesting that interventions should be tailored to different BMI categories. A Taiwanese observational cohort study found that low BMI was closely associated with all-cause and cardiovascular mortality (HR=1.92 and HR=1.74, respectively), with a U-shaped relationship between BMI and both outcomes, consistent with our findings.

Our stratified analyses by sex, age, and disease status further elucidated the BMI-mortality relationship. Low BMI significantly affected all-cause mortality in women and older adults without chronic comorbidities. In patients with coronary heart disease or hyperlipidemia, BMI's effect on all-cause mortality was not modified by these conditions, with low BMI remaining an independent risk factor. This suggests that certain chronic diseases such as hypertension, diabetes, and chronic lung disease may attenuate BMI's predictive value for mortality risk, whereas coronary heart disease and hyperlipidemia do not modify this relationship. For cardiovascular mortality, low BMI significantly increased risk in participants aged ≥ 80 years without chronic comorbidities, independent of malignant tumor status. The complex relationship between BMI and mortality requires further investigation, particularly through large clinical studies examining specific chronic diseases to confirm the special value of the "obesity paradox" in older populations.

These studies consistently demonstrate that low body weight is a risk factor for mortality, while the effect of overweight/obesity on mortality risk remains controversial. Some research indicates that overweight/obesity may increase the risk of cardiovascular disease, diabetes, and other health problems, thereby increasing mortality. However, other studies suggest that overweight may have protective effects, particularly in older adults—the "obesity paradox." HEIAT et al. analyzed 13 observational studies and found that among adults over 65 years followed for 3 years, obese older adults had reduced mortality risk. In individuals over 75 years, obese older adults showed no increased all-cause or cardiovascular mortality compared to those with normal BMI, regardless of sex. Other studies have shown that the relationship between BMI and mortality in older adults may be U-shaped or inverted J-shaped, with mortality risk increasing again when BMI exceeds 35-40 kg/m², though this increase is not substantial.

The increased mortality risk associated with low BMI in older adults may be related to malnutrition, which has been confirmed as a risk factor for adverse outcomes in this population. Weight loss is also a key component of frailty and malnutrition assessment criteria. Malnutrition may lead to decreased immune function and muscle loss, further exacerbating health risks in older adults. Additionally, research has found that low body weight is associated with cognitive decline in older adults, whereas no such association has been observed with obe-

sity. Therefore, attention to BMI and nutritional status is crucial for prognosis in older adults.

The “obesity paradox” remains controversial, with some scholars suggesting that among surviving overweight or obese older adults, there may be a “survival effect” where individuals susceptible to obesity-related complications may have already died, leaving a study population with greater resilience. Our study did not observe increased mortality risk with overweight or obesity, providing some evidence supporting the “obesity paradox” in older adults. For this population, greater attention should be directed toward underweight and malnourished individuals. Our study, with its relatively long follow-up period, found that low BMI is an independent risk factor for mortality, with no association observed between overweight/obesity and mortality. However, RCS curves suggest a U-shaped relationship between BMI and mortality, indicating that further research is needed to clarify the precise relationship between overweight/obesity and mortality risk.

This study has limitations. The diagnosis of overweight/obesity was based solely on BMI, which is the most commonly used metric but cannot distinguish between fat and muscle mass or accurately identify age-related changes in body composition, limiting its validity in older and very old adults. Future studies should employ dual-energy X-ray absorptiometry to accurately identify muscle and fat mass and clarify their respective effects and interactions on outcomes in older adults.

In conclusion, weight management in older adults cannot be overlooked, particularly for underweight individuals. The U-shaped relationship between BMI and mortality indicates that low BMI is an independent risk factor for mortality in this population. These findings suggest that weight management strategies for older adults should consider the differential effects of BMI on health outcomes and develop more targeted, individualized approaches for this special population.

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