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Original Study

Associations of Body Mass Index and Waist Circumference with 3-Year All-Cause Mortality Among the Oldest Old: Evidence from a Chinese Community-Based Prospective Cohort Study

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A B S T R A C T

Objective: Current international and national guidelines for body mass index (BMI) and waist circumference (WC) have been recommended to all adults. However, whether recommendations applied to the oldest old (aged 80+) is poorly known. The study objective was to investigate the relation of BMI and WC with 3-year all-cause mortality among the oldest old.
Design, Setting, and Participants: A total of 4361 Chinese oldest old (mean age 91.8) participated in this community-based prospective cohort study.
Measurements: BMI and WC were measured at baseline in 2011 and were used as continuous variables and as categorized variables by recommendations or by tertiles. Adjusted, sex-stratified Cox models with penalized splines and Cox models were constructed to explore the association.
Results: Greater BMI and WC were linearly associated with lower mortality risk in both genders. The mortality risk was the lowest in overweight or obese participants (BMI $\geq$ 24.0) and was lower in participants with abdominal obesity. Compared to the upper tertile, those in the middle and lower tertile of BMI had a higher risk of mortality for men [hazard ratio (HR): 1.23 (1.02-1.48) and 1.53 (1.28-1.82)] and for women [HR: 1.21 (1.03-1.41) and 1.35 (1.15-1.58)]; it was also found in participants in the middle and lower tertile of WC for men [HR: 1.21 (1.01-1.46) and 1.41 (1.18-1.69)] and for women [HR: 1.35 (1.15-1.58) and 1.55 (1.32-1.81)] (all the P values for trend <.001). These findings were robust in further sensitivity analyses or when using propensity score matching, in subgroup analyses, or in octogenarians, nonagenarians, and centenarians.
Conclusions: In Chinese oldest old, both higher BMI and higher WC predict better survival in both genders. The finding suggests optimal BMI and WC may be sensitive to age, thus, the current recommendations for the oldest old may need to be revisited.

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Informed consent was obtained from all participants and/or their relatives, and the study was approved by the Ethics Committee of Peking University.

The authors declare no conflicts of interest.

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In the general population, higher body mass index (BMI), an indicator of general obesity, and higher waist circumference (WC), an indicator of abdominal obesity, were well-recognized independent risk factors for cardiovascular disease and all-cause mortality.[1,2] However, aging is accompanied by restructuring of body composition and muscle loss,[3] and the excess risk of mortality due to higher BMI and WC decreases with age.[2,4] The relationship is less clearly defined in those aged 65+; most previous studies hold the view that the minimal mortality risk for this age group was at higher BMI (particularly for the overweight category) or higher WC values than those observed for middle-aged adults.[5]

Current international and national recommendations have adopted the same BMI and WC thresholds for all adults aged 18 or older, that is, independent of age.[6–9] The recommendations were based on well-established evidence in the young and middle-aged, while there has been an ongoing discussion regarding whether the same BMI and WC thresholds apply to the younger elderly and the oldest old (aged 80+ years). Some previous studies have revealed that higher BMI predicted better survival in the oldest old.[10–15] The unexpected manifestation of reverse epidemiology in the oldest old, which was also observed in persons with chronic illnesses,[16] was known as the obesity paradox. Although other studies have suggested that the association between BMI and mortality is decreasingly U shaped,[4] or that general obesity is not significantly associated with higher mortality after age 85 years[17] these studies demonstrate that much uncertainty remains about the optimal BMI in the oldest old.

The decrease in total body mass and redistribution of body fat occurs after the age of 60,[18] and WC is strongly related to visceral fat depots. Therefore, WC may provide a more accurate index of body fat than BMI in the oldest old.[5,19] However, most previous investigations of body weight and mortality have focused only on BMI, and the usefulness of WC as a predictor of mortality in the oldest old has not been established. Most prior studies have been conducted in North American and European populations.[4,10–16] The association of BMI and WC with mortality in these populations may differ from Asian populations, who are generally thinner and have higher body fat than North Americans and Europeans.[7,20] Additionally, most previous studies are limited by small sample sizes (less than 1000), self-reported BMI and WC, a large portion of missing BMI and WC data, unadjusted major confounders, and/or without exploring gender difference and age difference (octogenarians, nonagenarians and centenarians).[4,10–16] Our goal was to fill these gaps through an investigation of the relationship of objective BMI and WC with all-cause mortality in both genders among the Chinese oldest old in a large prospective community-based cohort study, accounting for major known confounders.

Methods

Study Participants

A total of 7328 older adults were included at baseline from the sixth wave of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) in 2011. The CLHLS has the largest sample of the oldest old in China, and is a longitudinal prospective cohort study conducted in 22 provinces of China. The details of the CLHLS and sample design have been described in our previous study.[21] We excluded 2967 participants because they were younger elderly (≤79 years; n = 2437), had incorrect death date (n = 43), or missed BMI and/or WC values (n = 487); leaving 4361 oldest old (1872 men and 2489 women; 1935 octogenarians, 1695 nonagenarians, and 731 centenarians) eligible for the study (Figure e1 in the Supplement). The study was approved by the Biomedical Ethics Committee of Peking University. All participants or their legal representatives signed written consent forms to participate in the baseline and follow-up survey.

Anthropometric Measurements

The anthropometric measurements included body weight, height, and WC. Height was measured to the nearest 1 cm and weight to the nearest 1 kg. BMI was computed as weight in kilograms divided by height in meters squared. WC was measured using a nonstretchable tape in centimeters at a level between the lowest rib and iliac crest with the subjects lightly clothed. Following the guidelines for Chinese, BMI were categorized into four categories: underweight (BMI < 18.5), normal weight (18.5 ≤ BMI < 24.0), overweight (24.0 ≤ BMI < 28.0), and obese (≥28.0).[7] Given that only 139 (3.2%) participants' BMI were higher than 28, this group was merged with the overweight group. Central obesity was defined as WC ≥85 cm in men or WC ≥80 cm in women.[7] Gender-specific tertiles of BMI and WC were created; the lower, middle, and upper tertiles were, respectively, <19.1, 19.1-22.0, and ≥22.0 for BMI in men; <18.2, 18.2-21.4, and ≥21.4 for BMI in women; <78, 78-86, and ≥86 cm for WC in men; and <73, 73-83, and ≥83 cm for WC in women.

Mortality

Survival status was ascertained during the follow-up survey in 2014, assessing whether subjects died and the date of death, completed the study, or were lost to follow-up. A "lost to follow-up" status was assigned to those who could not be found and contacted. Participants who survived or were lost to follow-up were censored at 3.0 years.

Statistical Analysis

All analyses were performed separately for men and women. In this cohort, few data were missing for potential confounders (1.1%); the missing data were corrected using multiple imputation methods. The 3-year all-cause mortality rate was estimated with the Kaplan-Meier product-limit method, and compared with the log-rank test. Cox models with penalized splines were used, which used penalized splines to fit Cox proportional hazards models to survival data for men and women, to explore whether the associations of BMI and WC with mortality were linear or nonlinear by Akaike information criterion (AIC).[22] Then the associations of BMI and WC with mortality were analyzed in univariate Cox proportional hazard models and in models adjusted for age (year), residence (urban or rural), educational background (year), current alcohol drinking, current cigarette smoking, disability in activities of daily living (ADL), cognitive impairment, hypertension and diabetes mellitus, cardiovascular diseases, stroke and cerebrovascular diseases, respiratory diseases, and cancer (the definition is in the Supplementary Material). The BMI and WC were analyzed as continuous variables, the results representing the estimated hazard ratios (HRs) and 95% confidential interval (CI) associated with 1 unit change in BMI and 1 cm change in WC, and as categorized variables by recommendations or by tertiles.

All analyses were conducted with SAS, version 9.4 (SAS Institute Inc, Cary, NC), except for the Cox models with penalized splines, which were carried out with R version 3.4.0 (R Core Team). Two-sided *P* values < .05 were regarded as statistically significant.

Sensitivity Analyses and Subgroup Analyses

Sensitivity analyses were performed by censoring at the midpoint of follow-up (1.5 years) or removing all lost-to-follow-up to clarify the impact of lost-to-follow-up. Exclusion of early mortality in the first year was performed to eliminate premature deaths from the analyses to reduce potential methodologic issues associated with disease-related weight loss. Additionally, with an attempt to reduce the effects of unbalanced confounding factors on the association, analysis