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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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Abstract

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Author contributions

Y.B.L., S.L., Z.X.Y., and X.G. conducted the data analysis, drafted and revised the manuscript. X.M.S. and Y.Z. designed the survey, reviewed, and revised this manuscript. V.B.K., C.M., J.Q.Y. and J.Z. helped to conduct data analysis and critically revised this manuscript, J.S.L. and H.S.C. helped to implement the survey, and review the manuscript. All authors read and approved the final manuscript.

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Conflicts of Interest: None.

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

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+) were poorly known. The study objective was to investigate the relationship 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 24.0 kg/m^2); and was lower in participants with abdominal obesity. Compared to the upper tertile, those in middle and lower tertile of BMI had 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 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 <0.001). These findings were robust in further sensitivity analyses, or using propensity score matching, or 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, the current recommendations for the oldest old may need to be revisited.

Keywords

body mass index; waist circumference; mortality; obesity paradox; oldest old

INTRODUCTION

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 was accompanied with restructuring of body composition and muscle loss [3], the excess risk of mortality due to higher BMI and WC decreased with age [2, 4]. The relationship was less clearly defined in those aged 65+; most previous studies held 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 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, i.e. 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+). 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. While other studies have suggested that the association between BMI and mortality is decreasingly U shaped⁴, or general obesity were not significantly associated with higher mortality after age 85[17]. These studies demonstrate that much uncertainty remains about the optimal BMI in the oldest old.

The decrease of total body mass and redistribution of body fat occurred after the age of 60 [18], WC was 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 Chinese oldest old in a large prospective community-based cohort study, accounting for major known confounders.

METHODS

Study participants

A total of 7328 elderly 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 (eFigure 1 in the Supplement). The study was approved by the 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 centimeter (cm) and weight to the nearest 1 kilogram (kg). BMI was computed as weight in kilograms divided by height in meters squared (kg/m^2). WC was measured using a non-stretchable 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 ($\text{BMI} < 18.5 \text{ kg/m}^2$), normal weight ($18.5 \leq \text{BMI} < 24.0 \text{ kg/m}^2$), overweight ($24.0 \leq \text{BMI} < 28.0 \text{ kg/m}^2$), and obese ($\text{BMI} \geq 28.0 \text{ kg/m}^2$) [7].

Given that only 139 (3.2%) participants' BMI were higher than 28kg/m², 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 tertile, middle tertile and upper tertile were <19.1 kg/m²; 19.1–22.0 kg/m², ≥ 22.0 kg/m² for BMI in men; <18.2 kg/m²; 18.2–21.4 kg/m², ≥ 21.4 kg/m² for BMI in women; <78 cm, 78–86 cm, ≥ 86 cm for WC in men; and <73 cm, 73–83 cm, ≥ 83 cm for WC in women, respectively.

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 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 non-linear 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 was in Supplements). The BMI and WC were analyzed as continuous variables, the results represented the estimated hazard ratios (HRs) and 95% confidential interval (CI) associated with 1 kg/m² 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, USA), except for the Cox models with penalized splines which were carried out with R version 3.4.0 (R Core Team). Two-sided p-value < 0.05 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 methodological issues associated with disease-related weight loss. Additionally, with an attempt to reduce the effects of unbalanced confounding factors on the association, analysis with propensity score matching (PSM) as a different approach was performed [23].

Since age, smoking habits, functional status and co-morbidity may confound the association and selection bias may be an explanation for this paradox [24], we ran a fully-adjusted model among different groups stratified by age (octogenarians, nonagenarians and centenarians), smoking status, ADL, cognitive function, co-morbidity, specific chronic disease (diabetes mellitus, cardiovascular diseases, stroke and cerebrovascular diseases and respiratory disease), and the interactions between these factors and BMI or WC for mortality risk were evaluated.

RESULTS

Baseline characteristics and 3-year all-cause mortality

At baseline, the average BMI and WC were 20.5 kg/m² and 80.3 cm, and were higher in men than women. The baseline characteristics were presented in eTable 1 in Supplement. During 3 years of follow-up, 1795 participants died, 2337 survived and 229 were lost-to-follow-up. The 3-year all-cause mortality was 41.2%, and the rate of lost-to-follow-up was 5.3%. In both genders, for BMI and WC, the 3-year all-cause mortality were significantly higher in upper tertile than lower and middle tertile ($p < 0.001$) (Figure 1).

Association of BMI with mortality

In Cox models with penalized splines, linear associations between BMI and mortality were identified for men and women on the basis of AIC (the AICs were lower for linear association than the non-linear, and the p-values for linear association were less than 0.001 for men and women). (Figure 2). After fully adjusted, each 1 kg/m² increment in BMI corresponded to a 5.0% decrease for men [HR:0.950(0.929–0.972)] and a 4.0% decrease for women [HR:0.960(0.943–0.977)] in 3-year all-cause mortality. (Table 1).

Compared to underweight participants, fully-adjusted models suggested that the mortality risk was lower in normal weight participants and overweight or obese participants: the HRs were 0.71(0.60–0.83) and 0.60(0.47–0.76) for men, and 0.80(0.70–0.91) and 0.79(0.64–0.96) for women. Compared to the participants in upper BMI tertile, those in middle and lower tertile of BMI had a higher risk of mortality with adjustment. In men, the HRs were 1.23(1.02–1.48) and 1.53(1.28–1.82) for middle and lower BMI (p for trend < 0.001). In women, the HRs were 1.21(1.03–1.41) and 1.35(1.15–1.58) for middle and lower BMI. (all the p-values for trend < 0.001).

Association of WC with mortality

Similarly, in Cox models with penalized splines, linear associations were identified between WC and mortality on the basis of AIC for men and women (the AICs were lower for linear association than the non-linear, and the p-values for linear association were less than 0.001 for men and women). ((Figure 2). After fully adjusted, each 1 cm increment corresponded to a 1.4% decrease for men and a 1.3% decrease for women in 3-year all-cause mortality. (Table 2).

Table 2 showed the association of WC with mortality according to the cut-points by Chinese recommendation and by tertiles. The HRs were lower in participants with abdominal obesity

than those with normal WC: 0.76(0.65–0.89) in men and 0.78(0.69–0.88) in women. Compared with participants in the upper WC tertile, those in the middle and lower tertiles of WC had a higher risk of mortality. In men, the HRs were 1.21(1.01–1.46) and 1.41(1.18–1.69) for middle and lower WC; in women, the HRs were 1.35(1.15–1.58) and 1.55(1.32–1.81) (all the p-values for trend <0.001). (Table 2).

Sensitivity analyses and subgroup analyses

When we excluded mortality in the first year or censored the lost-to-follow-up at 1.5 years or removed the lost-to-follow-up, all the findings were robust in both genders. Notably, when using PSM to balance confounding factors for the three BMI and WC groups, the results did not change our findings appreciably, the finding remained.(Table 1 and Table 2)

There were no significant interactions of BMI with most of the covariates for mortality risk, the reverse associations of BMI and WC with mortality were observed in those subgroups for both genders and total population. Although several covariates were significantly interacted with BMI, such as age group, smoking status, and cardiovascular diseases (all the p-values for interaction <0.05), similar results were observed in all those subgroups, mortality risk was the highest among those with lower BMI (Table e2). Interestingly, all the covariates were not significantly interacted with WC for mortality risk, the finding kept robust among all those subgroups. (Table e3). The reverse associations of BMI and WC with mortality were revealed in both genders and in octogenarians, nonagenarian and centenarians, while lower BMI predicted higher mortality risk than lower WC for men and octogenarians, lower WC predicted higher mortality risk than lower BMI for women and centenarians (Table 1, Table 2, eTable 1, eTable 2).

DISCUSSIONS

This study suggested that for the oldest old, greater BMI and WC predicted better survival over a 3-year period, in men and women, in octogenarians, nonagenarian and centenarians, independent of major known confounders. That is, underweight participants rather than the overweight or obese participants had the highest risk of mortality.

This study was consistent with the previous studies that revealed the reverse associations of BMI and WC with mortality in the oldest old, even though gender difference or nonagenarian and centenarians hasn't attracted much attention in those studies [10–14, 17]. Among 2249 Danish nonagenarians, those with the highest self-reported BMI (>28.0) had the lowest mortality [10]. Among 647 Finnish oldest old, the highest five year mortality was observed in the group with a BMI below 20.0 kg/m² and the lowest mortality in those with a BMI over 30.0 kg/m² [11]. Among Swedish oldest old, compared to participants with BMI below 25.0 kg/m², the overweight had a decreased mortality risk [12]. Among 568 community-dwelling Mexican Americans aged 85+, participants with obesity had a lower risk of mortality than normal weight elderly [13]. Among 697 Japanese oldest old, being overweight (BMI>25.0) was associated with longevity and underweight (BMI<18.5) with short life [14]. A recent study focusing on England oldest old found that the U-shaped association between BMI and mortality was non-significant, while the major known confounders have not been adjusted in this study, such as co-morbidity and functional

impairment [17]. Most of the previous studies [10–14, 17] were implemented in western populations (largely Caucasian), and have proved that the optimal BMI and WC were likely to increase with advancing age, the excess risk of mortality due to higher BMI and WC decreased with age, the finding for BMI and WC was firstly proved in Asian oldest old (Mongoloid) who were generally thinner than western populations. Previous research demonstrated that lower BMI and WC in elderly people were associated with increased all-cause mortality, also supported by this study.

To the best of our knowledge, only the Vitality 90+ Study evaluated the associations of both BMI and WC with mortality in 257 nonagenarians [15]; similar to our study, it showed that normal BMI showed a three times higher mortality risk than overweight, and WC was inversely associated with mortality.

Potential explanations for reverse associations of BMI and WC with mortality in the oldest old

In this Chinese cohort, higher BMI and WC were beneficial for survival in the oldest old. The reverse associations of BMI and WC with mortality were also observed with other classical cardiovascular risk factors, such as hypercholesterolemia[25] and hypertension[26], both of which seemed to decrease rather than increase the mortality risk in the oldest old. Such phenomena could be termed “reverse epidemiology” and/or “risk factor paradox”. The obesity paradox was first proposed from an unexpected finding that obese patients experienced a better survival than normal weight patients with terminal renal insufficiency and hemodialysis [16]. Later the obesity paradox was also found in various other chronic wasting diseases, such as cardiovascular diseases, surgical operations, cancer, HIV infection, respiratory diseases, and liver cirrhosis [27–31].

Several potential explanations have been proposed for the reverse associations of BMI and WC with mortality, including reverse causation bias, selection bias, survival bias, malnutrition-inflammation complex syndrome, the endotoxin-lipoprotein hypothesis, muscle mass and muscular strength, and toxic substances storage.[32] Taken together, these hypotheses suggest that causation is probably multifactorial.

Reverse causality bias was considered to be the major problem in the association. The oldest old were usually faced with higher health hazards than the middle-aged and younger elderly, a higher BMI and WC showed survival benefits, but only represented the absence of severe disease and a marker of health state as opposed to causality.[32] Another important potential cause of the reverse associations of BMI and WC with mortality may be a selection bias introduced in statistical analyses. Considering the direct acyclic graph (DAG) where lower BMI and WC may cause infectious diseases or functional impairment and then cause mortality, and they may share common causes that were independent of BMI and WC [24]. Our study attempted to mitigate reverse causality bias and selection bias by excluding the participants who died during the first years of the study, using PSM to minimize residual confounding, and conducting subgroup analyses such as excluding smokers, participants with identified chronic disease (including cardio-metabolic diseases) or functional impairment, and the reverse associations of BMI and WC with mortality remained.

It is possible that the reverse associations of BMI and WC with mortality may be a result of survival bias. The results of penalized spline curves in this study indicate that the linear relationship may only represented the left leg of the U-shaped relationship between BMI and mortality. Our study also supported this hypothesis because the average BMI and WC in the oldest old of this study were lower than the middle-aged and younger elderly. The reverse associations of BMI and WC with mortality may in part, be explained by differences in muscle mass and strength [33, 34]. The oldest old with lower BMI and WC had higher risk of sarcopenia, and may be less social and active, thereby increased the risk of bone loss, fractures, and cognitive decline [32–35], all of which were unfavorable to survival. Besides, some hormones released from adipose tissue have anti-inflammatory effects, and lower BMI and WC which were indicators of poor nutritional status [33–35]. Interestingly, fat tissue may contain a large number of pluripotent stem cells with a potential for tissue regeneration [36]. And adipose tissue can also provide a relatively safe storage site for toxic lipophilic chemicals (such as persistent organic pollutants), and thereby explain, at least in part, the reverse associations of BMI and WC with mortality [37].

The validity of BMI and WC as measures of obesity in the oldest old has been questioned as fat distribution changes with age in recent years. This study confirmed that not only BMI, but also other anthropometric index, such as WC, was good predictor of mortality for the oldest old. WC values for predicting mortality in those aged 80+ were different from those younger than 80, among which higher WC was a risk factor rather than a protective factor for mortality, and have similar predictive accuracy in identifying mortality risk compared with BMI. These results emphasized the importance of potential implications not only for BMI, but also for WC in the obesity definition and mortality risk identification. This study and previous studies [4,10–16] in oldest old provide compelling evidence for a negative association between BMI, WC and all-cause mortality, reminding us that current international and national guidelines [6–9] may not be appropriate for the oldest old, and the BMI and WC thresholds may be overly restrictive for the oldest old.

STRENGTHS AND LIMITATIONS

As far as we know, the current study had the largest sample size to assess the association of BMI and WC with mortality in both genders among oldest old, and was also the first study to investigate the role of WC in Asian oldest old. Our largest simple, including 1935 octogenarians, 1695 nonagenarians and 731 centenarians, allowed us to make meaningful conclusions for all those three age groups. Another strength of this study was the sample with objective rather than self-reported BMI and WC in the oldest old, and some important methodological issues that were explored to elucidate the reverse associations of BMI and WC with mortality phenomenon, made our results quite robust.

In this study, BMI and WC were estimated only once for each subject at baseline, so no conclusions can be drawn about the effect of lifetime exposure and fluctuations. The oldest old may have partly lost their height because of osteoporosis and/or kyphosis, therefore the calculated BMI may have been overestimated. Additionally, cause of death data were not collected because it is difficult to assess the cause of death in participants who were likely to suffer from various chronic diseases, especially among those who died at home rather than

in hospital. Finally, we were focusing on Chinese oldest old, thus results may not apply to other ethnic and age groups.

CONCLUSIONS

In this large community-based prospective cohort study, both higher BMI and higher WC predict better survival among Chinese oldest old in both genders, and in octogenarians, nonagenarians and centenarians. These data suggest that current international and national recommendations focusing on the risks of excess BMI and WC in the oldest old, may need to be revisited, more attention should be paid in estimating the mortality risk of lower BMI and WC; the optimal BMI and WC may be sensitive to age, gender and ethnicity, underscoring the importance of providing Asian-specific and gender-specific guidelines for optimal BMI and WC in this age group.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. The 3-year all-cause mortality in different BMI and WC tertiles by gender

For men, the 3-year all-cause mortality was 40.7%, and were significantly higher in participants with upper BMI and WC level ($p < 0.001$); the mortality was 48.9%, 39.3% and 34.4% for participants with lower, middle and upper BMI (Figure 1a), and 45.7%, 41.0% and 35.8% for participants with lower, middle and upper WC (Figure 1b). For women, the 3-year all-cause mortality was 41.5%, and were significantly higher in participants with upper BMI and WC level ($p < 0.001$); the mortality was 49.4%, 42.3% and 33.0% for participants with lower, middle and upper BMI (Figure 1c), and 49.9%, 43.5% and 32.4% for participants with lower, middle and upper WC (Figure 1d).

Figure 2. The associations of BMI and WC with mortality for men and women in Cox models with penalized splines

The lines depict the estimated hazard ratio of BMI or WC for 3-year all-cause mortality in men and women, and the dotted lines indicate the 95% confidence intervals. In Cox models with penalized splines, linear associations of BMI and WC with mortality were identified for men and women on the basis of AIC (the AICs were lower for linear association than the non-linear, and the p-values for linear association were less than 0.001 for men and women).

Table 1.

The 3-year all-cause mortality in relation to BMI.

BMI	Crude models ^a		Adjusted models ^b		Propensity score matching ^b	
	Men (n=1872)	Women (n=2489)	Men (n=1872)	Women (n=2489)	Men (n=1455)	Women (n=1896)
Continuous variable						
Each 1 kg/m ² increment	0.947(0.926–0.968) **	0.934(0.918–0.951) **	0.950(0.929–0.972) **	0.960(0.943–0.977) **	0.938(0.914–0.962) **	0.966(0.947–.985) **
Cut-offs by recommendation						
Underweight (< 18.5 kg/m ²)	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference
Normal weight (18.5–24.0 kg/m ²)	0.68(0.58–0.80) **	0.70(0.61–0.80) **	0.71(0.60–0.83) **	0.80(0.70–0.91) **	0.66(0.55–0.79) **	0.85(0.73–0.98) **
Overweight or Obese (≥ 24.0 kg/m ²)	0.58(0.46–0.73) **	0.62(0.51–0.75) **	0.60(0.47–0.76) **	0.79(0.64–0.96) *	0.54(0.41–0.71) **	0.85(0.68–1.05)
P-value for trend	<0.001	<0.001	<0.001	0.001	<0.001	0.013
Cut-offs by BMI textiles						
Lower	1.58(1.33–1.88) **	1.71(1.47–1.99) **	1.53(1.28–1.82) **	1.35(1.15–1.58) **	1.50(1.23–1.83) **	1.29(1.09–1.54) **
Middle	1.21(1.01–1.45) *	1.36(1.17–1.60) **	1.23(1.017–1.48) *	1.21(1.03–1.41) *	1.23(1.011.52) *	1.12(0.94–1.32)
Upper	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference
P-value for trend	<0.001	<0.001	<0.001	<0.001	<0.001	0.004

Abbreviations: BMI, body mass index.

* p<0.05;

** p<0.01.

^a unadjusted hazard ratio and 95% confidential interval.^b Adjusted for age (year), residence, educational background (year), current alcohol drinking, current cigarette smoking, disability activities of daily living, cognitive impairment, hypertension, diabetes mellitus, cardiovascular diseases, stroke and cerebrovascular diseases, respiratory disease and cancer.^c The lower tertile, middle tertile and upper tertile BMI were <19.1 kg/m²; 19.1–22.0 kg/m², 22.0 kg/m²; 21.4 kg/m², 21.4 kg/m² for men; <18.2 kg/m², 18.2–21.4 kg/m², 21.4 kg/m² for women, respectively.

Table 2.

The 3-year all-cause mortality in relation to WC.

WC	Crude models ^a		Adjusted models ^b		Propensity score matching ^b	
	Men(n=1872)	Women (n=2489)	Men (n=1872)	Women (n=2489)	Men (n=1455)	Women (n=1896)
Continuous variable						
Each 1cm increment	0.986(0.979–0.993) **	0.979(0.974–0.985) **	0.986(0.979–0.993) **	0.987(0.982–0.992) **	0.986(0.978–0.994) **	0.987(0.982–0.993) **
Cut-offs by recommendation						
Non-abdominal obesity	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference
Abdominal obesity (>85cm for men, >80cm for women)	0.78(0.67–0.91) **	0.67(0.59–0.76) **	0.76(0.65–0.89) **	0.78(0.69–0.88) **	0.74(0.63–0.88) **	0.79(0.68–0.90) **
Cut-offs by WC tertiles						
Lower	1.37(1.15–1.83) **	1.80(1.55–2.10) **	1.41(1.18–1.69) **	1.55(1.32–1.81) **	1.49(1.23–1.82) **	1.52(1.28–1.80) **
Middle	1.19(0.99–1.42)	1.47(1.26–1.72) **	1.21(1.01–1.46) *	1.35(1.15–1.58) **	1.23(1.02–1.49) *	1.08(0.92–1.27)
Upper	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference	1.00 reference
P-value for trend	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Abbreviations: WC, waist circumference.

* p<0.05;

** p<0.01.

^a unadjusted hazard ratio and 95% confidential interval.^b Adjusted for age (year), residence, educational background (year), current alcohol drinking, current cigarette smoking, disability in activities of daily living, cognitive impairment, hypertension, diabetes mellitus, cardiovascular diseases, stroke and cerebrovascular diseases, respiratory disease and cancer.^c The lower, middle and upper tertile WC were <78 cm, 78–86 cm, 86 cm for men; and <73 cm, 73–83 cm, 83 cm for women, respectively.