Waist circumference, body mass index and mortality across age groups in 17.3 million adults: a prospective cohort study

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► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/jech-2025-225506).

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Received 12 November 2025
Accepted 5 October 2026

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To cite: Yi S-W, Cho J-J, Ohrr H. *J Epidemiol Community Health* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/jech-2025-225506

ABSTRACT

Background Waist circumference (WC) has limited clinical utility due to reliance on single sex-specific thresholds without accounting for body mass index (BMI) and age. We aimed to examine the detailed joint association of BMI and WC with mortality by sex and age.

Methods In this prospective cohort study, 8 905 225 men and 8 347 590 women who underwent routine health screening during 2009–2010 were followed through June 2024 for all-cause mortality. Measured WC was categorised into 5 cm intervals within each of 15 BMI categories, enabling detailed joint stratification.

Results During a mean follow-up of 13.9 years, 955 725 men and 615 825 women died. Both high and very low WC were associated with increased mortality across all BMI categories (12–50 kg/m²). Each 5 cm increase in WC was associated with 16% (95% CI 1.16 to 1.17) and 14% (95% CI 1.14 to 1.15) higher mortality in men and women, respectively, with WC at or above age- and BMI-specific median. BMI-specific WC ranges and BMI–WC combinations associated with lowest mortality shifted upward with age. Individuals with 5 cm lower WC and 2–3 unit lower BMI exhibited similar mortality compared with normal or slightly overweight individuals with BMI-specific high WC.

Conclusions We found a robust J-shaped association between WC and mortality within 15 BMI categories, more pronounced at older ages. Our large-scale mortality-based evidence may help refine BMI-specific WC thresholds by age and provide an empirical basis for individualised obesity management across BMI–WC profiles. In non-obese individuals with BMI-specific high WC, WC reduction without necessarily pursuing weight loss may represent a more beneficial strategy for longevity.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Clinical utility of waist circumference (WC) has been limited by reliance on single sex-specific thresholds and a predominant focus on weight loss for obesity management.

WHAT THIS STUDY ADDS

⇒ We quantified the joint BMI–WC–mortality relationship by age with unprecedented resolution, providing an empirical basis for obesity risk stratification across BMI–WC profiles.

⇒ Both high and very low WC were associated with increased mortality across all BMI categories, with J-curve associations more pronounced at older ages

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Large-scale mortality-based evidence from this study may help refine BMI-specific WC thresholds by age.

⇒ In non-obese individuals with BMI-specific high WC, targeting WC reduction without necessarily pursuing weight loss may offer better longevity benefits, underscoring the importance of tailoring obesity management to BMI–WC profiles.

INTRODUCTION

Obesity, characterised by excess adiposity,[1] is a major contributor to global disease burden.[2] Nearly half of adults worldwide were affected by overweight and obesity in 2021.[3] Body mass index (BMI) remains the most widely used obesity metric, though it can misclassify obesity, leading to underdiagnosis or overdiagnosis.[4–6] Accordingly, experts recommend supplementing BMI with additional measures including waist circumference (WC), waist-to-height ratio and waist-to-hip ratio.[1]

WC is the most commonly recommended complementary measure worldwide.[6–9] However, its clinical utility remains limited, as guidelines use single sex-specific thresholds (eg, ≥88 cm for White women and ≥102 cm for White men),[6–9] despite broad agreement that optimal thresholds differ by age and BMI.[6] Establishing WC thresholds requires understanding joint BMI–WC association with health risks through detailed cross-classification.[10] All-cause mortality—a hard endpoint—may reflect the full spectrum of health risks associated with excess adiposity. Among prospective studies investigating WC–mortality associations across BMI categories,[10–17] large-scale cross-classification studies using at least five categories for each measure suggested linear WC–mortality associations within BMI strata,[10 11] but provided limited insight into detailed risk patterns across age and BMI.

In this prospective cohort of 17.3 million adults, we assessed the combined association of BMI and WC with all-cause mortality, stratified by sex and age. Using detailed BMI and WC classifications, we aimed to determine patterns and magnitudes of the associations including apparent optimal BMI-specific WC ranges and BMI–WC combinations

associated with the lowest mortality. Because body composition, fat distribution and disease prevalence vary with age,[18] our age-stratified analyses aimed to help refine WC thresholds for identifying high-risk obesity phenotypes at all ages.[1 6]

METHODS

Study population and follow-up

In South Korea, the National Health Insurance Service (NHIS) covers approximately 97% of the population and provides biennial health examinations. During 2009–2010, 17 733 108 individuals aged 18–99 years received routine health examinations. The participation rates among eligible individuals were 66.0% in 2009 and 68.2% in 2010. After excluding those with incomplete information or extreme anthropometric values (n=480 293), 17 252 815 participants were followed for mortality through the NHIS eligibility database until 30 June 2024 (online supplemental eFigure 1), in which death status is updated through linkage with the national resident registration system.[19 20]

This study was approved by the Institutional Review Board of Catholic Kwandong University, which waived informed consent due to data anonymisation.

Data collection

WC was measured at the narrowest point between the lower border of the rib cage and the iliac crest (cm).[15] Height and weight were measured to the nearest centimetre and kilogram, respectively, to calculate BMI (kg/m^2).[21] Standard BMI terminology was applied: underweight (<18.5), normal (18.5–24.9), overweight (25–29.9), obese (≥30), class I obese (30–34.9) and severe obese (≥35). Fasting glucose and cholesterol levels were analysed enzymatically. Systolic blood pressure was measured after ≥5 min rest. Participants completed questionnaires on physical activity, alcohol consumption and smoking status. Data collection followed standardised governmental protocols, with external quality assessments.[21]

Statistical analysis

BMI was categorised into 15 categories (kg/m^2; <19 (12–18.9), 19–29.9 by 1-unit intervals, 30–32.4, 32.5–34.9, ≥35 (35–50)). WC was categorised by 5 cm intervals and into 12 groups for the univariable associations of WC with mortality. For BMI–WC joint associations, within each sex-specific BMI category (all ages combined), WC was divided into 4–7 groups, each containing at least 5000 participants. For example, men with BMI 25–25.9 kg/m^2 were classified into seven WC groups (<75, 75–79, … 95–99, ≥100 cm), while women with BMI 32.5–34.9 kg/m^2 were classified into five WC groups (<90, 90–94, 95–99, 100–104, ≥105 cm). Age was categorised as 18–49, 50–64 (setting 50 years as the cut-off for post-menopausal changes),[21 22] 65–74 and 75–99 years.

Hazard ratios (HRs) and 95% confidence intervals (95% CI) for mortality were estimated using Cox models with follow-up time as the time scale. Multivariable models adjusted for age (continuous), income quartiles (Q1–Q4), smoking status (current, former, never smoker, or missing), alcohol use (<1, 1–2, 3–4, 5–7 days/week, or missing) and physical activity (moderate (≥30 min/session) or vigorous (≥20 min/session): none, 1–2, ≥3 times/week). Potential mediators of adiposity effects were additionally included in sensitivity analyses[23 24] as three-level status variables integrating measured biomarker levels with known disease status, to evaluate the extent to which the observed associations might be explained by these intermediate factors: systolic blood pressure (<120, 120–139 and ≥140 mm Hg or known hypertension), fasting glucose (<100, 100–125 and ≥126 mg/dL or known diabetes) and total cholesterol (<200, 200–239, and ≥240 mg/dL or lipid-lowering medication use). Additionally, diabetes prevalence was presented by sex, age, BMI and WC categories.

HRs per 5 cm increase in WC were calculated at or above, and below, the sex-, age- and BMI-specific median WC, derived separately for each stratum. Participants were classified according to the median WC of their corresponding sex-age-BMI stratum. For example, among men aged 18–49 years, the median WC was 70 cm at BMI 19–19.9 and 102 cm at BMI 32.5–34.9. Thus, a 42-year-old man with BMI 19.8 kg/m^2 and WC 73 cm would be classified as at or above the median, whereas a 38-year-old man with BMI 33.1 kg/m^2 and WC 100 cm would be classified as below the median. Stratified analyses by age, BMI, smoking, disease status and follow-up duration were performed, also serving as sensitivity analyses.

We additionally summarised WC ranges within each BMI category that were associated with relatively low excess mortality risk. Specifically, WC intervals linked to ≤5% and ≤15% higher mortality risk—compared with the lowest-risk group—were labelled as apparent optimal and acceptable ranges.[21] Apparent optimal BMI–WC combinations were similarly presented. The term 'optimal' referred to the lowest observed mortality and did not imply causality.

No exclusions based on smoking, disease or early mortality were made, as such exclusions could introduce bias.[1 25] However, in analyses of HRs per 5 cm increase in WC, we additionally stratified by follow-up duration (<5 years, 5–10 years and ≥10 years); thus, deaths occurring before 10 years were excluded in the ≥10-year stratum. Heterogeneity across groups was assessed with Cochran's Q statistic. Given the low proportion of missing data (2.7%), we used complete-case analysis, which is unlikely to introduce substantial bias. All tests were two-sided, using SAS version 9.4 (SAS Institute Inc, Cary, NC, USA).

RESULTS

Baseline characteristics

During a mean follow-up of 13.9 years, 955 725 (10.7%) of 8 905 225 men and 615 825 (7.4%) of 8 347 590 women died. At baseline, the mean age was 49.6 years for women and 47.2 for men; mean WC was 76.4 and 83.8 cm, and mean BMI was 23.2 and 24.2 kg/m^2, respectively (online supplemental eTables 1 and 2). Hypertension, diabetes and hyperlipidaemia prevalence increased with higher BMI. In men, average WC rose until the early 50s and declined after the mid-70s (online supplemental eFigure 2). In women, WC increased from the mid-20s to the mid-70s, then declined. The most frequent WC categories were 69–71, 75–77, 81–83 and 78–80 cm among women aged 18–49, 50–64, 65–74 and 75–99 years, respectively (online supplemental eFigures 3 and 4).

Waist circumference and BMI versus mortality

WC exhibited a U-shaped association with mortality, with the lowest risk at 80–94 cm in men and 75–89 cm in women (figure 1). BMI also showed a U-shape, with nadirs at 24–27.9 kg/m^2 in men and 23–26.9 kg/m^2 in women.

Combined analysis of waist circumference and BMI on mortality

WC had a J-shaped association with mortality within each BMI category (figure 2). Both high and very low WC were associated with increased mortality across all BMI ranges (12–50 kg/

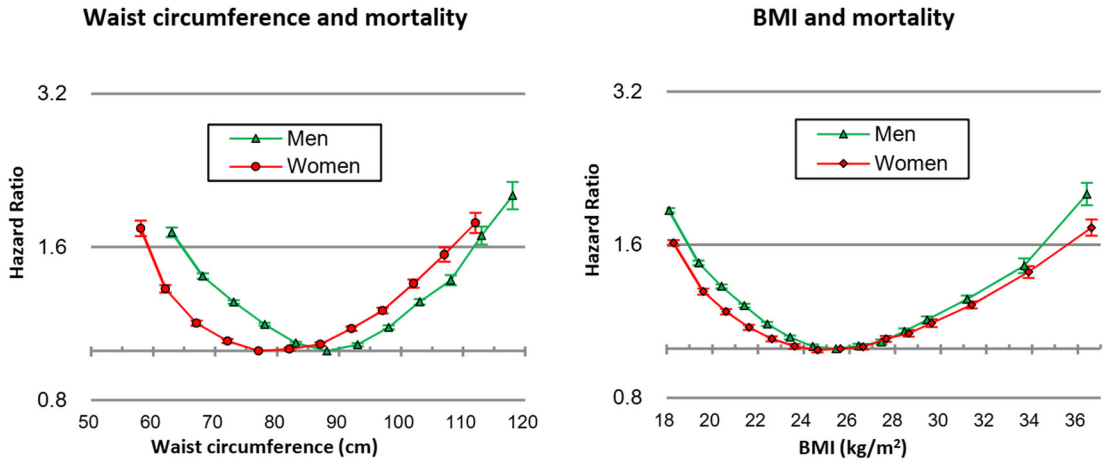


Figure 1 Hazard ratios (HR) for mortality associated with waist circumference and body mass index (BMI) by sex. HR and 95% CI were calculated after adjustment for age, household income, smoking status, alcohol use frequency and physical activity. Waist circumference (WC) analyses were not adjusted for BMI, and BMI analyses were not adjusted for WC. WC was categorised into 12 groups (men: <65, 65–69, … 85–89 (reference), 90–94, … 110–114, ≥115 cm; women: <60, 60–64, … 80–84 (reference), … 105–109, ≥110 cm). BMI was categorised into 15 groups (<19, 19–19.9, … 25–25.9 (reference), 26–26.9, … 29–29.9, 30–32.4, 32.5–34.9, 35–50 kg/m^2). The midpoint was used as a representative value of each WC and BMI category, except both ends for which the median was used.

m^2) and ages (figure 3). The J-curve became more pronounced with age, particularly among women ≥75 years, approaching a more U-shaped pattern. In men 50–64 years (online supplemental eTable 3), BMI 21–21.9 with WC 85–89 cm (HR 1.71, 95% CI 1.64 to 1.78) or BMI 20–20.9 with WC 80–84 cm (HR 1.78, 95% CI 1.71 to 1.84) showed higher mortality than BMI 29–29.9 with WC 85–89 cm (HR 1.21, 95% CI 1.10 to 1.33) or WC 100–104 cm (HR 1.55, 95% CI 1.46 to 1.64), illustrating that even WC below the Korean cut-off (90 cm) in normal-weight men could confer greater risk than WC above the cut-off in overweight men. In women 65–74 years (online supplemental eTable 4), HRs with WC 85–89 cm were 1.31 (95% CI 1.25 to 1.37, BMI 23–23.9), 1.25 (95% CI 1.20 to 1.31, BMI 24–24.9), 1.18 (95% CI 1.13 to 1.23, BMI 25–25.9) and 1.12 (95% CI 1.07 to 1.17, BMI 26–26.9), respectively, compared with 1.38 (95% CI 1.32 to 1.45) for BMI 25–25.9 with WC 90–94 cm, using BMI 25–25.9 with WC 75–79 cm as the reference, indicating that lowering WC while maintaining weight was associated with lower mortality than weight loss with WC reduction. Associations between BMI and mortality within each 5 cm WC category were U-shaped (online supplemental eFigure 5). Furthermore, within each WC group, optimal BMI range shifted upward with increasing WC (online supplemental eTables 3 and 4).

Hazard ratios per 5 cm increase in waist circumference

Given the J-shaped associations, analyses were stratified by sex-, age- and BMI-specific median. At or above the median, each 5 cm increase in WC was associated with 16% (95% CI 1.16 to 1.17) and 14% (95% CI 1.14 to 1.15) higher mortality in men and women, respectively (figure 4), whereas below the median, the corresponding estimates were modest (1% in men and −1% in women; online supplemental eFigure 6). After additional adjustment for blood pressure, glycaemic and lipid status, HRs at or above the median were 1.14 (95% CI 1.14 to 1.15) for men and 1.13 (95% CI 1.12 to 1.13) for women. Without stratification by median WC, HRs were 1.10 (95% CI 1.09 to 1.10) in men and 1.08 (95% CI 1.08 to 1.08) in women (online supplemental eFigure 7). Risk estimates peaked at ages 50–64 and declined thereafter. In six-age-group sensitivity analyses, risk estimates peaked at ages 60–69 in men and at ages 50–59 in women (online supplemental eFigure 8). Subgroup analyses showed the lowest HRs in BMI <19 kg/m^2 and the highest in male never-smokers, individuals with hyperlipidaemia and during the first 5 years of follow-up within their respective subgroups (figure 4).

Apparent optimal WC ranges within BMI groups and BMI–WC combinations

Apparent optimal ranges were shown in figure 5 and online supplemental eFigure 9. For example, among women with BMI 23–23.9 kg/m^2, WC ranges associated with the lowest mortality were 65–74 cm (aged 18–49) and 70–84 cm (aged 75–99). Age-related shifts in low-risk combinations were evident: subsets of BMI 20–22.9 with WC 60–74 cm (aged 18–49), BMI 22–26.9 with WC 60–79 cm (aged 50–64), BMI 23–27.9 with WC 65–84 cm (aged 65–74), and BMI 24–29.9 with WC 75–89 cm (aged 75–99) in women. Additionally, the 5 cm WC categories including the 85th percentile generally showed elevated risk and were not part of apparent optimal ranges, regardless of sex and age (online supplemental eFigures 9 and 10). The optimal BMI–WC combinations for mortality did not necessarily correspond to those with the lowest diabetes prevalence (online supplemental eFigure 11).

DISCUSSION

We found a J-curve association between WC and mortality across BMI categories from 12 to 50 kg/m^2, consistent by sex and age. Both high and very low WC were associated with increased mortality within each BMI group. The excess mortality associated with low WC became more pronounced with age, especially in women aged 75–99. The WC ranges associated with lowest mortality within each BMI category increased with higher BMI and with advancing age. BMI–WC combinations linked to the lowest mortality also shifted upward with age, particularly among women. Among individuals with WC at or above the sex-, age-, and BMI-specific median, each 5 cm increase in WC was associated with 16% and 14% higher mortality in men and women, respectively; this association was weakest in individuals

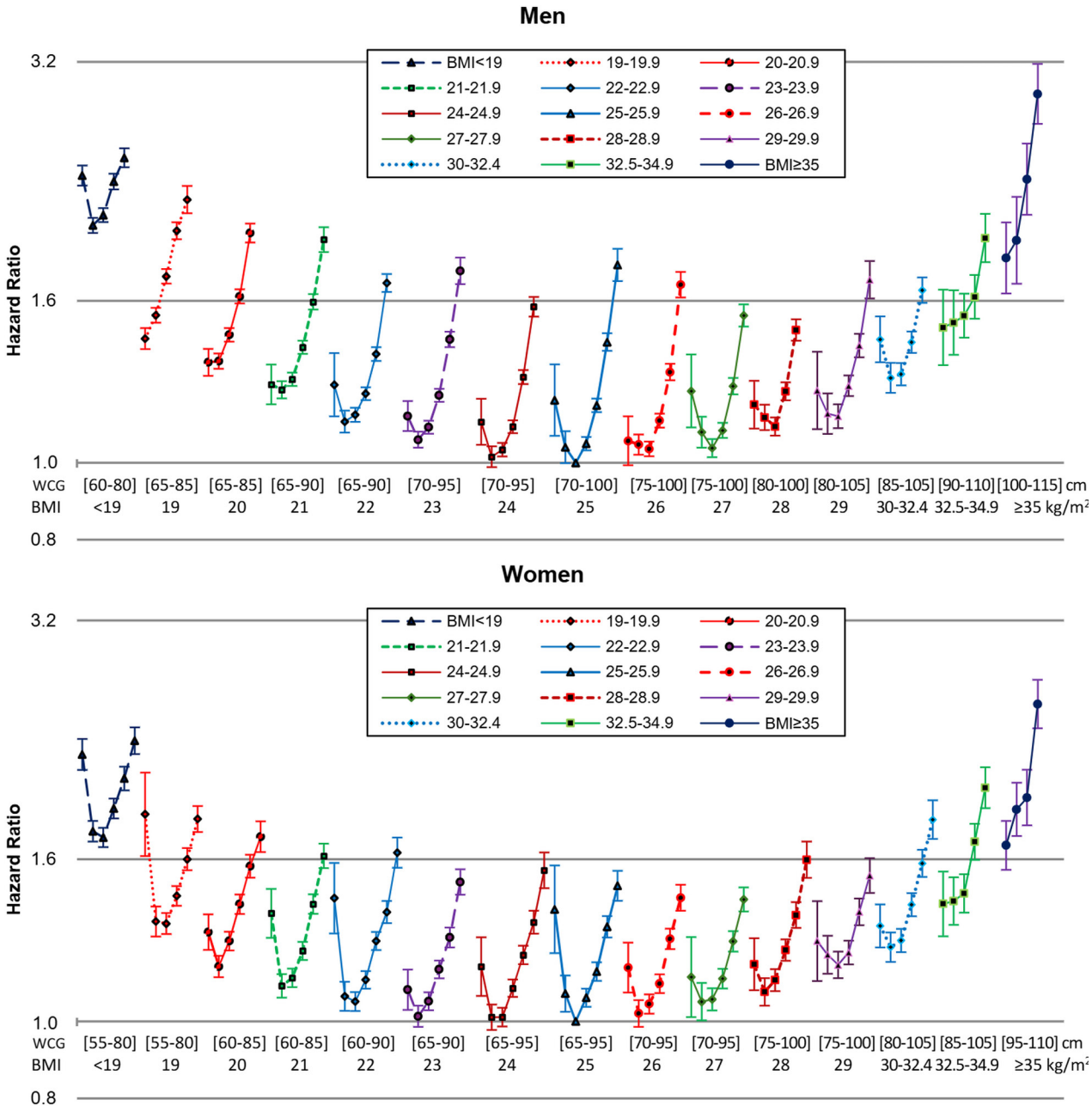


Figure 2 Hazard ratios (HR) for mortality according to waist circumference (WC) within 15 body mass index (BMI) categories. HR and 95% CI were calculated after adjustment for age, household income, smoking status, alcohol use frequency and physical activity using a BMI of 25–25.9 kg/m^2 and WC of 80–84 cm (men) or 75–79 cm (women) as the reference. WCG (waist circumference group) [60–80] indicates WC <65, 65–69, 70–74, 75–79 and ≥80 cm; WCG [100–115] indicates WC <105, 105–109, 110–114 and ≥115 cm.

with BMI <19 kg/m^2 and strongest among male never-smokers, individuals with hyperlipidaemia and during the first 5 years of follow-up within their respective subgroups.

In contrast to previously suggested linear associations,[10 11] we found a robust J-shaped association between WC and mortality across BMI categories. Some studies that used fewer than four BMI strata have suggested non-linear WC–mortality associations.[12] However, broad BMI groups meant low WC often coincided with low BMI, obscuring WC's independent effect. These findings are therefore not directly comparable to our study across 15 BMI categories.[10] Prior studies that cross-classified at least five BMI categories reported linear associations, but they applied uniform WC groups across BMI, despite substantial differences between underweight and obese individuals. For example, 96% (Korean) and 62% (White) of underweight participants clustered into the lowest WC category, limiting assessment of very low WC risk. Our detailed BMI-specific WC categorisation addresses this, clearly demonstrating J-curve associations.

Higher-than-optimal WC was associated with greater mortality within each BMI category. A prior systematic review, based on studies that did not stratify by BMI, reported 5% higher all-cause mortality per 5 cm increase in WC in models without BMI adjustment (n=50 studies) and 8% with BMI adjustment (n=15).[26] These figures are not directly comparable to our larger

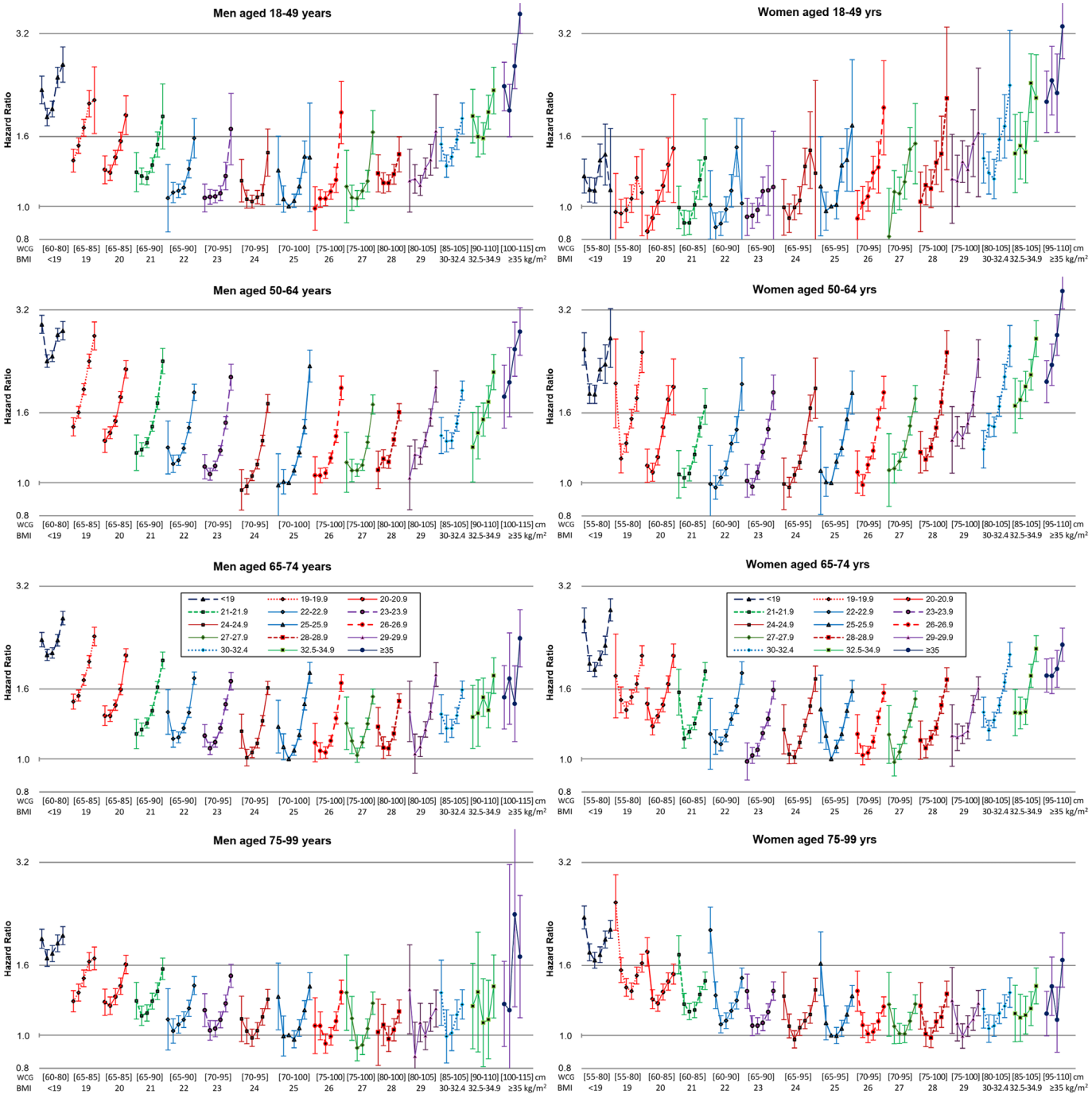


Figure 3 Hazard ratios (HR) for mortality according to waist circumference within 15 body mass index (BMI) categories by age group. Analyses were stratified by age group and otherwise performed using the same method as in figure 2. WCG, waist circumference group.

estimates (16% in men, 14% in women), which are based on BMI-specific analyses at or above the BMI-specific median WC, thereby targeting the ascending limb of the J-curve. Given the complex BMI–WC–mortality relationship observed, treating BMI categorically or as a simple linear term may oversimplify these associations. Notably, risk estimates varied notably by age, peaking at 50–64, lowest at 75–99; 65–74 exceeded 18–49 years. Contrary to previous research suggesting stronger associations in youngest adults,[10 21 26] we found a clear peak at 50–69 years, confirmed in six-age-group sensitivity analyses. This may reflect broader BMI-specific WC ranges associated with the lowest mortality in youngest adults, with greater muscle mass and lower visceral fat mitigating risk from elevated WC.[18]

Most studies establishing ethnicity-specific WC thresholds including Korean studies used the presence of obesity-related cardiometabolic diseases as criterion for excess adiposity.[9 27] Overweight individuals with optimal WC generally had more cardiometabolic diseases, yet tended to live longer than normal-weight individuals.[10 13 14] Korean clinical guideline cut-offs, derived from cardiometabolic morbidity (WC ≥85 cm in women, ≥90 cm in men for abdominal obesity),[9] do not align well with our mortality-based findings: overweight individuals just above

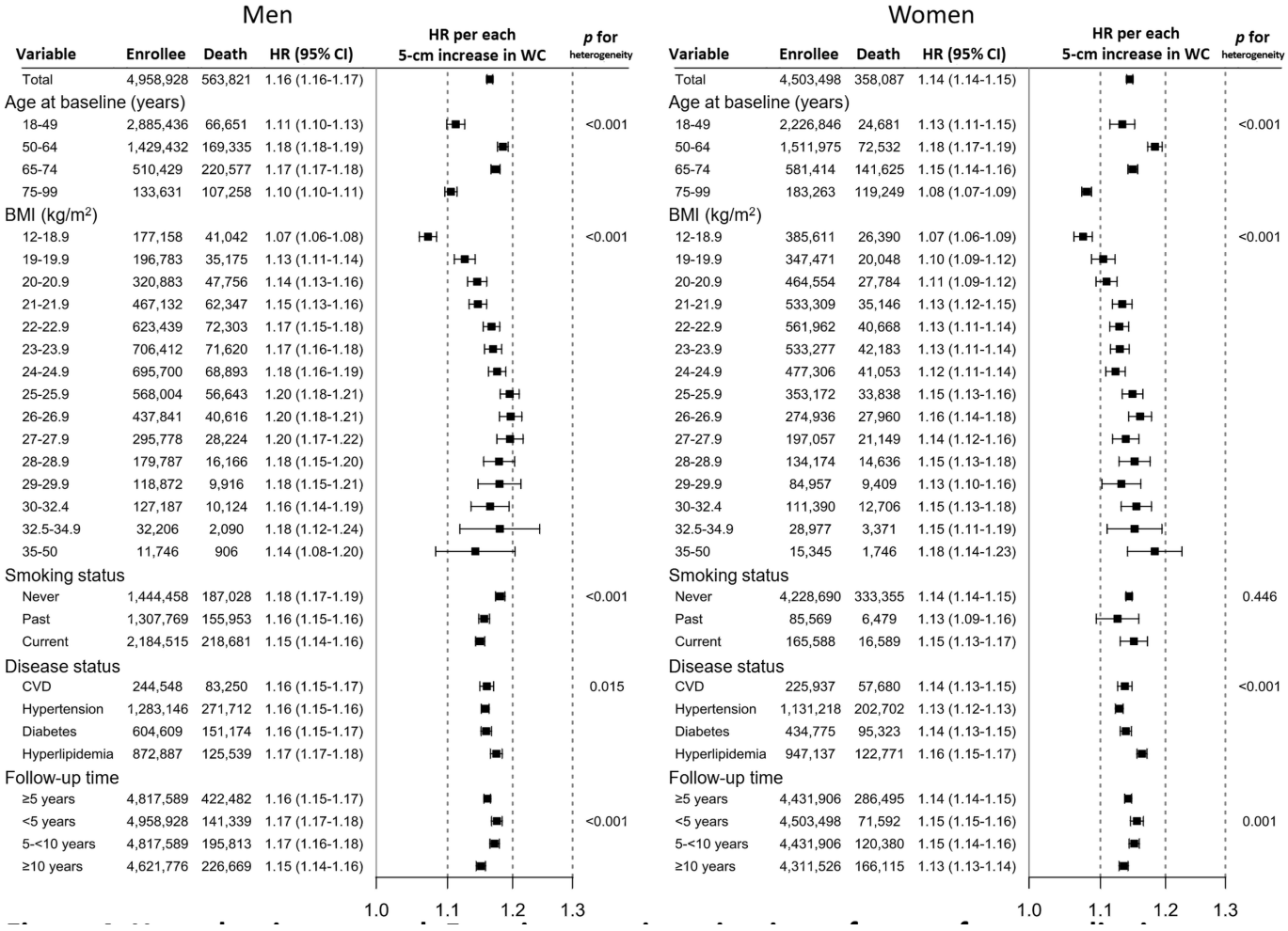


Figure 4 Hazard ratios (HR) per each 5 cm increase in waist circumference (WC) for mortality in individuals with WC at or above the sex-, age- and body mass index (BMI)-specific median. HR and 95% CI were estimated using Cox models stratified by BMI (15 categories via the STRATA statement) and adjusted for age, household income, smoking status, alcohol use frequency and physical activity. BMI subgroup analyses were separately conducted within each BMI category. In smoking-stratified analyses, smoking status was omitted from the adjustment covariates, whereas age was retained as a continuous covariate in age-stratified analyses. Otherwise, the adjustment covariates were identical to those used in the primary analysis. Cardiovascular disease (CVD) was defined as ≥1 clinical visit for heart disease (I20–I52) or stroke (I60–I69) within 1 year before screening; hypertension was defined as systolic blood pressure ≥140 mm Hg or ≥1 clinical visit for hypertension (I10–I14); diabetes was defined as fasting glucose ≥126 mg/dL or ≥1 clinical visit for diabetes (E10–E14); and hyperlipidaemia was defined as total cholesterol ≥240 mg/dL or ≥1 prescription for lipid-lowering agents within 6 months before screening. Follow-up time was categorised as: ≥5 years (after 5 years), <5 years (first 5 years), 5–<10 years (second 5 years), ≥10 years (after 10 years). P values for heterogeneity across follow-up time groups were calculated between the three groups: <5 years, 5–<10 years, and ≥10 years.

these thresholds had higher diabetes prevalence (online supplemental eFigure 11),[28] but lower mortality than normal-weight individuals just below them. Collectively, this evidence indicates that while cardiometabolic morbidity is important, it cannot fully explain the health risks of excess adiposity.[1] Prioritising all-cause mortality alongside obesity-related morbidities may better establish anthropometric thresholds to identify higher risk obesity phenotypes and guide management across the diverse health risks associated with obesity.[1]

Recently, it has been broadly recognised that WC thresholds should vary by BMI and age.[6 18 27] However, empirical data directly linking BMI–WC-specific patterns by age with mortality have been scarce.[12] The homogeneous Korean population, with narrow genetic diversity, allowed unusually precise delineation of BMI–WC–mortality patterns by age that may have been obscured in heterogeneous cohorts.[29] Our analyses provide large-scale mortality-based evidence demonstrating how optimal WC ranges vary jointly by BMI and age. We observed systematic upward shifts in the apparent optimal WC ranges with advancing age, reflecting physiological change in body composition and fat distribution.[18] Integrating WC distributions with these mortality patterns further suggests that BMI-specific percentiles, such as the 85th,[30] may serve as practical interim thresholds. Overall, these findings extend prior frameworks by providing empirical guidance for refining BMI- and age-specific WC thresholds.

If confirmed to be causal, our detailed joint analyses delineate how optimal adiposity management for longevity differs across BMI–WC profiles, providing an empirical basis for individualised obesity management. For individuals with obesity, especially severe obesity, weight loss accompanied by WC reduction was most advantageous, consistent with established recommendations. In those with class I obesity with BMI-specific high WC,

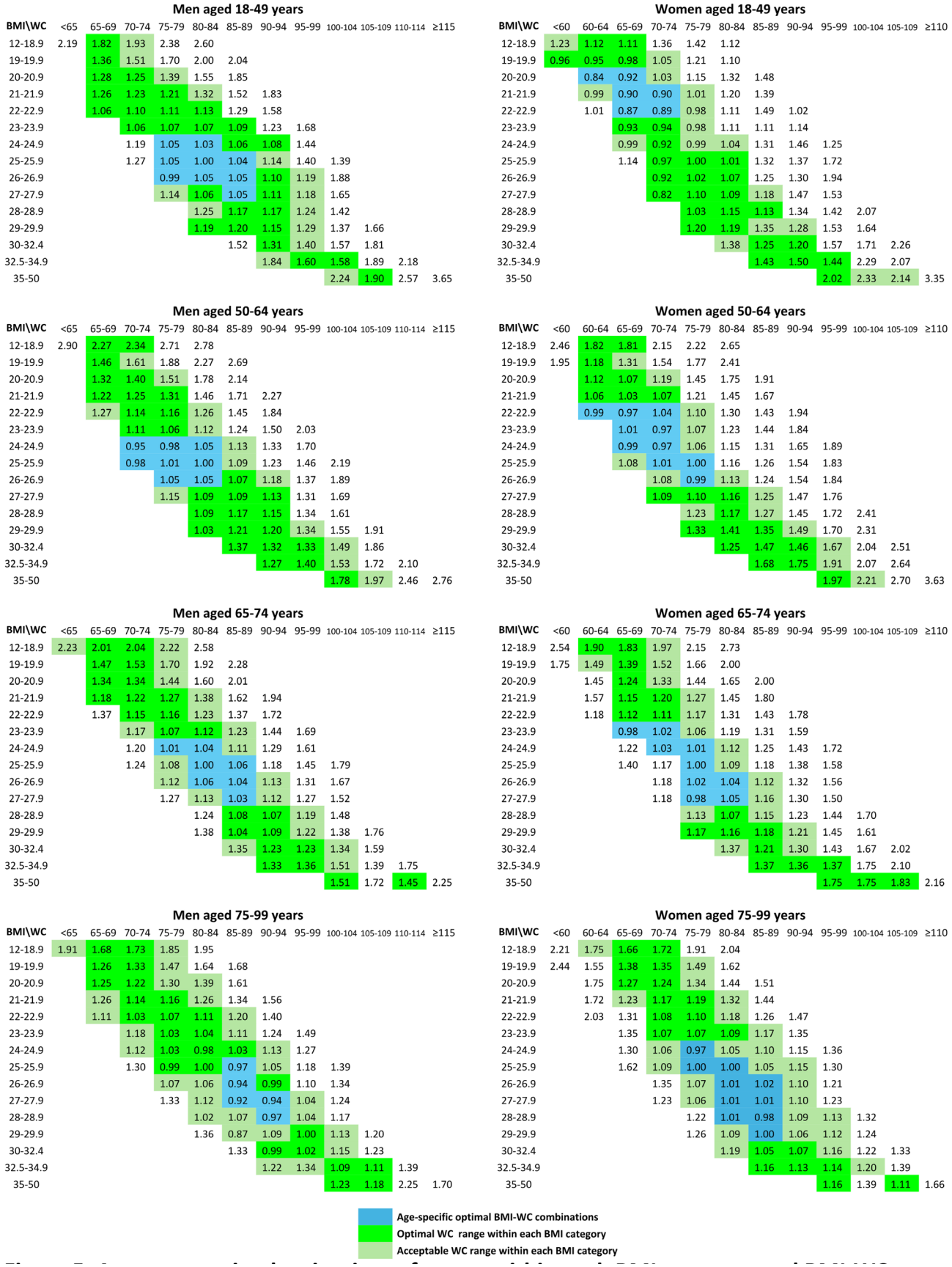


Figure 5 Apparent optimal waist circumference (WC) within each body mass index (BMI) category and BMI–WC combinations by age groups. Hazard ratio values are the same as those presented in figure 3 and online supplemental eTables 3 and 4. The smallest and largest WC categories within each BMI group include individuals with WC values below or above the indicated category.

WC reduction without additional weight loss was similarly beneficial compared with weight loss with concurrent WC reduction. In overweight individuals within the BMI-specific lowest-risk WC ranges, risk differences from the optimal combinations were not large, suggesting limited need for aggressive intervention. By contrast, in individuals with normal-weight or overweight but BMI-specific excess WC—particularly those in the highest WC categories—WC reduction without necessarily pursuing weight loss appeared to confer greater survival benefit than weight loss accompanied by WC reduction. For example, in normal-weight individuals with excess WC, 5 cm lower WC and 2 unit lower BMI (8–10% lower weight) generally were not associated with lower mortality. In overweight individuals with BMI-specific excess WC, such combinations (7–8% lower weight) were associated with lower mortality; nonetheless, 5 cm lower WC with the same BMI showed even lower mortality. These patterns suggest that the way WC reduction is achieved—whether accompanied by weight loss or not—may lead to different physiological consequences.

Achieving WC reduction without weight loss, primarily through energy balance exercises,[31 32] indicates visceral fat reductions alongside gains in fat-free mass, predominantly muscle. Increased muscle mass correlates with improved cardiorespiratory fitness,[33] both independently reducing mortality.[34 35] Conversely, WC reduction with weight loss typically results from caloric restriction.[36 37] During such weight loss, non-obese individuals proportionally lose more muscle mass than obese individuals,[36] potentially offsetting the benefits of visceral fat loss. This disproportionate loss may explain why, in our study, individuals with 5 cm lower WC and 2–3 unit lower BMI exhibited overall similar or increased mortality compared with normal or slightly overweight individuals with BMI-specific high WC.

This study has several strengths. It included the largest number of deaths reported to date, enabling high statistical power, detailed BMI and WC categories, and age-stratified analysis. The prospective cohort design minimised the recall and selection biases inherent to retrospective studies. BMI and WC were measured. As participants were recently recruited, findings may better reflect current populations. Inclusion of ethnically homogeneous individuals in a shared healthcare system likely reduced unmeasured confounding. Effect modification and reverse causality from smoking, disease and early deaths were examined through stratified analyses. Nearly complete follow-up via national database linkage was another strength.

There are limitations, however. The observational design limits causal inference. Some of the observed associations, particularly the stronger J-curve among the oldest adults, may partly reflect selective survival, confounding by pre-existing illness, or competing risk, which cannot be excluded in an observational design. Healthy volunteer bias cannot be entirely excluded; however, given the relatively high participation rate (approximately two-thirds) and the finding that the association between WC and mortality did not differ materially between all participants and those with pre-existing diseases (figure 4), this bias is less likely to be substantial. Data on non-participants were unavailable to assess this formally. Only all-cause mortality was assessed. WC and BMI were assessed only at baseline and changes in these variables during follow-up could not be accounted for, which may have influenced the observed associations. The homogeneity of the Korean population may also limit generalisability. Nonetheless, the consistent J-shaped associations observed across detailed BMI categories, sex, and age groups with differing cardiometabolic risk profiles support the robustness and potential relevance of the findings.

CONCLUSION

Our study highlights that both high and very low WC were associated with higher mortality within 15 BMI categories, with J-shaped associations more pronounced with age. The BMI-specific WC range associated with the lowest mortality shifted upward with higher BMI and, to a lesser extent, with age. Our detailed joint analysis of BMI and WC by age, including apparent optimal ranges and percentile thresholds, may help refine obesity risk stratification to promote longevity. Our findings highlight that strategies for managing excess adiposity should be tailored to the BMI–WC profile across age groups. While weight loss is the prevailing focus of current guidelines, our results indicate that, in non-obese individuals with BMI-specific high WC, WC reduction without necessarily pursuing weight loss may represent a more beneficial strategy for longevity.

Acknowledgements This research used data provided by the National Health Insurance Service of Korea (NHIS-2024-1-264, NHIS-2026-06-1-015).

Contributors S-WY conceived the study concept and design, acquired the data, and wrote the first draft. All authors analysed and interpreted the data and contributed to critical revision of the manuscript. All authors gave final approval and agreed to be accountable for all aspects of work ensuring integrity and accuracy. All authors had the final responsibility for the decision to submit for publication. S-WY is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. During the course of preparing this work, the authors used ChatGPT-4-o and ChatGPT-5 for the purpose of English proofreading. Following the use of this tool/service, the authors formally reviewed the content for its accuracy and edited it as necessary. The authors take full responsibility for all the content of this publication.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author). The authors have no financial or non-financial competing interests to declare.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the Institutional Review Board of Catholic Kwandong University (Gangneung, Republic of Korea, CKU-21-01-1803).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The data used in this study are available from the National Health Insurance Service (NHIS) of Korea (https://nhiss.nhis.or.kr/en/z/a/001/lpza001m01en.do). Access requires NHIS approval and is not publicly available.

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