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Body Volume Index, a novel obesity metric, and mortality: comparison with established obesity measures

Hwa-Young Lee

diana0224@gmail.com

The Catholic University of Korea https://orcid.org/0000-0003-2591-1436

Youngeun Son

Namsu Kim

Geonmin Jeon

Chansoo Kim

Dong Wook Shin

Sungkyunkwan University

Dong Wook Kim

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Abstract

BACKGROUND

Obesity is a major public health concern, yet conventional anthropometric indicators such as body mass index (BMI) show inconsistent associations with mortality, including the obesity paradox.

OBJECTIVE

This study introduces the Body Volume Index (BVI)—a novel 3D ellipsoid shape-based obesity indicator capturing central body dimensions relative to body mass—and evaluates its performance in predicting mortality against established measures.

METHODS

We analyzed data from 288,331 Korean adults in the National Health Insurance Service–National Sample Cohort (2009–2019). Five obesity indicators—BMI, waist-to-height ratio (WHtR), a body shape index (ABSI), body roundness index (BRI), and BVI—were categorized into sex-specific deciles (Q1-Q10, with Q5 as the reference). Associations with all-cause and cancer-specific mortality were assessed using multivariable Cox proportional hazards models adjusted for sociodemographic factors, health behaviors, and comorbidities.

RESULTS

In fully adjusted models, BMI showed a reverse J-shaped association with all-cause and cancer-specific mortality. WHtR and BRI paradoxically exhibited inverse or non-monotonic associations with mortality outcomes (e.g., for WHtR among men, adjusted hazard ratio [aHR] of all-cause mortality:1.27, 95% CI 1.13–1.42 for Q1 vs. Q5). Conversely, ABSI and BVI showed consistent positive linear trends with all-cause mortality in both sexes (e.g., for men in Q10 vs. Q5, aHR 1.58, 95% CI 1.41–1.77 for ABSI; and aHR 1.20, 95% CI 1.09–1.32 for BVI). Although ABSI showed steeper gradients for all-cause mortality than BVI, its association with cancer mortality was more variable.

CONCLUSIONS

BVI demonstrated stable positive associations with mortality outcomes alongside ABSI. Given its straightforward geometric formulation and wider numerical variability, BVI may offer favorable practical feasibility for risk stratification in large-scale epidemiologic contexts.

INTRODUCTION

Obesity is a major public health concern worldwide. It is closely associated with a wide range of chronic conditions—including cardiovascular diseases (CVD), cancers, arthritis—and is linked to mental health disorders like depression and anxiety, thereby imposing a substantial burden on individuals, families and society [1], and ultimately increasing mortality [2]. According to the Global Burden of Disease Study 2021, high BMI was responsible for approximately 2.13 million deaths among women and 1.69 million deaths among men in 2021, representing a 2.5-fold increase compared with 1990 [3].

Korea is no exception. Data from the 2022 Korea National Health and Nutrition Examination Survey showed that the prevalence of obesity among Korean adults reached 47.7% in men and 25.7% in women, with a continuing upward trend among adolescents [4]. In this context, there is a critical need for obesity indicators that can reliably predict obesity-associated morbidity and mortality risks at both individual and population levels, while remaining simple, cost-effective, and feasible for large-scale use.

Body Mass Index (BMI) is the most widely used indicator for defining obesity and is calculated as an individual's body weight divided by height squared. Its popularity is largely attributable to its ease of calculation and reasonable ability to predict the risk of several chronic conditions. However, BMI has several important limitations. Accumulating evidence suggests that individuals with the same body weight can have different health risks depending on their muscle-to-fat ratio and the distribution of body fat, particularly abdominal adiposity; however, BMI is derived from body weight and height and does not account for fat distribution. BMI demonstrates a generally linear association with the risk of hypertension and Diabetes Mellitus (DM) [5, 6], yet numerous studies have reported an "obesity paradox", whereby BMI is inversely associated with adverse health outcomes [7–9]. Waist circumference (e.g., > 85 cm for females and > 90 cm for males) is often used in conjunction with BMI, but it does not fully address these limitations and requires additional measurement procedures [10].

To overcome these shortcomings, several alternative anthropometric indicators have been proposed. The Waist-to-Height Ratio (WHtR), calculated as waist circumference divided by height, has demonstrated a stronger association with the risk of DM and CVD compared to BMI. However, its correlation with mortality has been reported to be weak [11, 12].

In 2012, Krakauer and Krakauer (2012) introduced another new metric, A Body Shape Index (ABSI), which incorporates the waist circumference relative to BMI [13]. While ABSI has been found to correlate positively with visceral fat mass [14] and to outperform BMI and waist circumference in predicting mortality risk [15], evidence indicates that its accuracy was lower in assessing health risk among younger or healthier individuals [16, 17] and for conditions beyond CVD, such as musculoskeletal conditions or cancers [18, 19].

More recently, the Body Roundness Index (BRI), which estimates body shape and fat distribution, quantifying the eccentricity of a two-dimensional elliptic cross-section using waist circumference and height, has been proposed. However, prior studies have reported a U-shaped association between BRI and all-cause mortality [20], and limited clinical applicability due to computational complexity.

All these indicators, although developed to address the limitations of BMI, have their own limitations, and therefore, there remains a need for more robust obesity indicators to better predict adverse health outcomes. Thus, we propose a novel single obesity index, the Body Volume Index (BVI), which quantifies obesity by modeling the human body as a three-dimensional ellipsoid and standardizing its estimated volume against actual body mass. This study aimed to evaluate the validity of BVI by examining its association with all-cause mortality, and cancer-related mortality, and comparing its performance with established obesity measures, including BMI, WHtR, ABSI, BRI.

MATERIALS AND METHODS

Data source and study population

We used the National Health Insurance Service-National Sample Cohort (NHIS-NSC) in Korea covering the period 2009–2019. The NHIS-NSC was established in 2006 by selecting a nationally representative sample of approximately one million individuals (representing 2.2% of the total population) from the national population enrolled in the National Health Insurance (NHI) and Medical Aid schemes via stratified random sampling based on sex, age, eligibility status, and income level.[18] The database contains comprehensive longitudinal information on births, deaths, insurance premiums, diagnostic codes, and healthcare utilization, including diagnostic tests and medical treatments. Crucially, it also includes detailed anthropometric measurements required to calculate obesity indicators—such as height, weight, and waist circumference—collected from the NHIS health screening program, which is fully subsidized by the government and provided biennially to beneficiaries aged 20 years or older.

The initial study population comprised individuals who underwent at least one NHIS health screening in 2009 and 2010, yielding a baseline cohort of 363,270 individuals. We restricted the enrollment window to these two years because waist circumference—a key variable for this analysis – has been consistently measured since 2008, and the NHIS health screening is offered on a biennial basis. For participants who underwent multiple health screenings during the enrollment window, parameters were extracted from the earliest screening. Participants were followed from the index date (defined as the date of the first health screening) until death or the end of the follow-up (December 31, 2019), whichever came first. To minimize confounding and mitigate potential reverse causation, we excluded individuals who died during the enrollment period (n = 1,124) and those with a history of cancer, CVD, or cerebrovascular disease prior to 2009 (n = 65,470). We further excluded individuals with missing values for anthropometric measurements (height, weight, or waist circumference) or covariates (n = 8,345). Consequently, the final analytic sample consisted of 288,331 individuals, comprising 149,288 men and 139,043 women. The proportion of observations excluded due to missing values was 2.81% (Figure S1 in Supplementary material).

Anthropometric indicators of obesity

This study evaluated a newly proposed anthropometric indicator, the BVI, and compared its association with mortality against four established obesity indicators: BMI, WHtR, ABSI, and BRI. The indicators were calculated as follows:

$$\mathrm{BMI}\left(\frac{kg}{m^2}\right) = \frac{Weight\,(kg)}{Height(m)^2}$$

$$\mathrm{WHtR}\ = \frac{WC\,(cm)}{Height\,(cm)}$$

$$\mathrm{BRI} = 364.2 - 365.5\ \times \sqrt{1 - \ (\frac{WC\,(cm)}{2\pi})^{\ 2}\ /(0.5\ \times\ Height\,(cm))^2}$$

$$\mathrm{ABSI}\ \left(\frac{m^{\frac{11}{6}}}{kg^{\frac{2}{3}}}\right) = \frac{WC\,(m)}{BMI(\mathrm{kg}/m^2)^{2/3} \times\ Height\,(m)^{1/2}}$$

$$\mathrm{BVI}\ \left(\frac{cm^2}{kg}\right) = \frac{WC\,(cm) \times\ Height\,(cm)}{18 \times\ Weight\,(kg)}$$

BVI was developed to approximate three-dimensional (3D) body volume using readily accessible clinical measurements. By integrating waist circumference (WC) and height, and subsequently standardizing the estimated volume against actual body weight, BVI is specifically designed to comprehensively capture the geometric characteristics of body shape relative to total body mass.

Although the recently proposed BRI also incorporates concepts of body shape and fat distribution, it exhibits distinct differences from BVI in its geometric assumptions and variable configurations. Specifically, BRI utilizes only height and WC to model the human body as a two-dimensional (2D) elliptic cross-section, subsequently quantifying the eccentricity of this ellipse. To achieve this, BRI employs a complex mathematical transformation to geometrically adjust for the degree to which an individual's profile deviates from a perfect circle. However, because body weight is entirely excluded from its formula, BRI captures only the spatial silhouette or “shape” of the body, and fails to account for substantial variations in tissue mass, such as skeletal muscle or bone density, among individuals with identical body outlines. Fundamentally, BRI is a non-linear transformation of the WHtR.

In contrast, BVI adopts a more intuitive and advanced approach by modeling the human body as a 3D ellipsoid. Specifically, by assuming the WC represents a circular perimeter, the horizontal semi-axes of the ellipsoid are defined as WC/2π while the vertical semi-axis is approximated as half of the individual's height to compute the 3D volume.

Furthermore, by dividing this calculated volume by the actual body weight, BVI introduces a physical concept analogous to specific volume (the reciprocal of density). This allows BVI to indirectly yet

scientifically reflect variations in body composition through the relative relationship between spatial volume and mass. A comprehensive step-by-step mathematical derivation of the BVI formula is provided in Supplementary Methods 1.

Variables

The primary outcomes of this study were all-cause mortality and cancer mortality. Cancer mortality was defined as death with the underlying cause coded as C00–C97 according to the Korean Standard Classification of Disease, 10th Revision (KCD-10).

The primary exposure variables of interest were the five obesity indicators (BMI, WHtR, ABSI, BRI and BVI). Since the primary objective of this study was to evaluate and compare the overall patterns of mortality risks associated with newly proposed BVI against four existing indicators under identical conditions—rather than to identify an optimal diagnostic cut-off point for clinically meaningful obesity—participants were categorized into sex-specific deciles. The detailed ranges for each decile are presented in Table S1.

To control for potential confounding, several baseline covariates were included: age (< 30, 30–39, 40–49, 50–59, 60–69, and ≥ 70 years), residential area (Seoul, metropolitan cities [the six metropolitan municipalities], small cities, and rural areas), income level (< 30%, 30–59%, 60–89%, and ≥ 90%), and smoking status (never-smokers vs. ever-smokers [defined as former or current smokers]) and alcohol consumption (non-drinker, low-risk, medium-risk, and high-risk groups according to World Health Organization criteria; Table S2). Income was operationalized using the NHI premiums as a proxy, which are determined based on the salary of wage earners or the asset value of self-employed and unemployed individuals. Comorbidities included diabetes mellitus (KCD-10 codes E10-E14) and hypertension (KCD-10 codes I10-I13, and I15).

Statistical Analysis

Participant characteristics are presented as frequencies and percentages, stratified by sex. Cumulative crude mortality (%) for all-cause and cancer deaths was calculated within each decile of the obesity indicators as the number of deaths divided by the initial number of participants at baseline with that decile. In addition, we generated heatmaps to illustrate the joint distribution of BMI deciles against the deciles of the other four obesity indicators (WHtR, ABSI, BRI, and BVI).

The associations between obesity levels and mortality outcomes were evaluated using multivariable Cox proportional hazards regression models. For these analyses, the deciles of each obesity indicator were entered as categorical variables, with the fifth decile designated as the reference group. The models were adjusted for the aforementioned baseline covariates. Separate regression models were constructed for all-cause mortality and cancer-specific mortality. The proportional hazards assumption was assessed using Schoenfeld residuals, and no major violations were detected. Adjusted hazard ratios

(HRs) across deciles of each obesity indicator were visualized by fitting a moving average trend line (with a window size of 2 deciles). Complete case analysis was applied to handle missing data, and all statistical analyses were stratified by sex and conducted using SAS (Version 9.4; SAS Institute Inc., Cary, NC, USA).

RESULTS

Descriptive statistics

Of the 363,270 eligible adults, a total of 288,331 participants were included in the final analytic cohorts. The cohort was followed up from 2009 to 2019, yielding a mean follow-up duration of 10.78 years overall (10.77 years for males and 10.82 years for females).

The baseline characteristics of the study sample, stratified by sex, are summarized in Table S3. Women were slightly older than men and a greater percentage of women belonged to the lowest income group (0–30%). In contrast, adverse health behaviors were substantially more prevalent among men. During the follow-up period, cumulative crude mortality was higher among men than women for both all-cause death (5.3% vs. 3.1%) and cancer-specific deaths (1.6% vs. 0.9%) (Table S3).

Joint distribution of WHtR, ABSI, BRI, and BVI deciles across BMI deciles

Figures 1 and 2 illustrate the joint distribution of WHtR, ABSI, BRI, and BVI deciles across BMI deciles (Q1–Q10) for men and women, respectively. Both WHtR and BRI exhibited a high degree of linear concordance with BMI, as evidenced by a heavy concentration of participants along the primary diagonal axis in men. More than half of individuals in the lowest BMI decile (Q1) were also classified into the lowest decile of WHtR (56.1%) and BRI (55.7%). Similarly, men in the highest BMI decile (Q10) were predominantly clustered in the top deciles of WHtR (53.5%) and BRI (53.1%).

In contrast, ABSI demonstrated a highly dispersed and slightly negative alignment with BMI across deciles. For instance, among men, individuals in the lowest BMI decile (Q1) were most frequently classified into the highest ABSI deciles (Q10: 16.5%), whereas those in the highest BMI decile (Q10) were most commonly found in the lowest ABSI decile (Q1: 15.8%).

BVI exhibited a generally positive but markedly weaker relationship with BMI. Although men in the lowest and the highest BMI deciles were most often classified into the corresponding lowest and the highest BVI deciles (19.8% and 16.9%, respectively), these proportions were modest compared with those observed for WHtR or BRI. A broadly similar joint pattern was observed among women for WHtR, BRI, and BVI (Fig. 2).

Association between obesity level and mortality

Cumulative crude mortalities across deciles of the five obesity indicators are presented in Table S4 and visualized in Fig. 3. For BMI, both all-cause and cancer-specific mortality exhibited a distinct inverse gradient across deciles among men, with higher crude mortality observed at lower BMI levels. In contrast, a modest but steady increase in cumulative crude mortality was observed across increasing BMI deciles among women.

For WHtR, a generally positive association with both all-cause and cancer mortality was observed in both sexes; however, the upward trend across deciles was non-monotonic, particularly among men. ABSI demonstrated a steeper upward gradient for both sexes, which followed a J-shaped trajectory rather than a strictly linear pattern. Both BRI and BVI displayed a steady and consistent increase in crude mortality across deciles for both all-cause and cancer mortality. However, the mortality discrepancy between the lowest and highest deciles was more pronounced for BVI than for BRI (Table S4 in Supplementary material).

Fully-adjusted cox proportional hazards regression analysis revealed distinct risk trajectories across the five indicators, with notable differences by sex (Figs. 4 and 5, and Table S5 in Supplementary material). Among men, the overall risk patterns were broadly similar for all-cause and cancer-specific mortality within each respective indicator. BMI demonstrated a reverse J-shaped association with both outcomes (Fig. 4); compared with the median decile (Q5), the risk of all-cause and cancer-specific mortality peaked at the lowest BMI decile (Q1), declined through Q8, and showed a marginal increase at Q10 (Table S5).

WHtR and BRI exhibited nearly identical trajectories in their adjusted associations with mortality (Fig. 4). In contrast to the crude mortality patterns—where cumulative crude mortality increased with higher deciles—the adjusted analyses revealed inverse associations between obesity level and both all-cause and cancer-specific mortality for these two indicators (Table S5).

Among all indicators, ABSI showed the most consistent and pronounced positive association with all-cause mortality, showing a steep risk elevation starting from the median decile; men in the highest ABSI decile experienced a 1.58–fold higher risk of all-cause mortality than those in Q5 (95% CI 1.41–1.77). However, its association with cancer-specific mortality was unstable (Table S5). BVI demonstrated a steady, linear increase in risk for all-cause and cancer-specific mortality across deciles; however, its slope was more gradual and showed fluctuation compared to that observed for ABSI (Fig. 4).

Among women, the adjusted risk patterns for all-cause mortality generally mirrored those observed in men (Fig. 5) (Table S5). For cancer-specific mortality, none of the five obesity indicators exhibited a clear increasing or decreasing trend among women (Fig. 5).

DISCUSSION

In this study, we introduced a newly developed obesity measure, the BVI, which conceptually differs from existing anthropometric indicators by emphasizing the 3D spatial body volume of an ellipsoid per unit of body mass. Specifically, unlike BMI, which is a simple measure of mass relative to height, WHtR, which

captures abdominal adiposity without accounting for body mass, and BRI, which models the human body shape as a 2D elliptic cross-section, BVI estimates actual 3D body volume using an ellipsoid-based geometric formula and subsequently normalizes this volume by body weight. Rather than relying on predefined obesity categories, we compared the varying associations between mortality and five obesity indicators—BMI, WHtR, ABSI, BRI, and BVI— across sex-specific deciles within a large-scale Korean population. Although no single indicator demonstrated unequivocal superiority across all endpoints and subgroups, our findings reconfirmed the well-described paradoxical association between BMI and mortality while suggesting the potential utility of BVI, alongside ABSI, as an alternative to BMI.

Recent studies estimating risks for all-cause mortality across BMI categories in Korea have consistently reported a J-shaped or reverse J-shaped association. In these studies, the lowest mortality was typically observed at overweight BMI levels around 25 kg/m², with risk increasing as BMI deviates above or below this level [7, 21]. Our findings align with this established trajectory; in both men and women, all-cause and cancer mortality risks peaked in the lowest BMI decile (Q1), reached their nadir in the 8th decile—corresponding to a BMI range of 25.6–26.5 kg/m² for men and 24.4–25.6 kg/m² for women.

Much of the earlier evidence supporting this “obesity paradox” has primarily focused on patients with CV disease. For instance, two large-scale meta-analyses pooling data from patients with established coronary artery disease—one encompassing 58 cohort studies (n = 578,780) and the other spanning 40 studies (n = 250,152)—demonstrated a clear survival advantage among overweight individuals compared to those with normal weight, and higher risks among underweight individuals [8, 22]. Accumulating evidence over the past decade indicates that this survival advantage conferred by modestly higher body weight is not confined to CVD populations but extends to other clinical contexts, including chronic obstructive pulmonary disease [23, 24], malignancies [25, 26], and critically ill patients in intensive care units [27].

The association between BMI and cancer mortality in previous studies has been more heterogeneous and appears to vary by cancer type. Several studies have reported null or inverse associations between obesity and cancer mortality among patients with certain malignancies, such as renal cell carcinoma [28]. Conversely, prospective cohort studies conducted among cancer-free populations have shown that obese individuals have significantly higher risks of both overall cancer mortality and site-specific cancer mortality [29–32]. Similar associations have also been observed among breast cancer survivors, in whom obesity has been linked to poorer prognosis and reduced survival [33]. These mixed findings likely reflect heterogeneity in study populations, varying degrees of control for confounding factors, follow-up durations, and differences in the timing of BMI measurement relative to cancer diagnosis.

Given the limited ability of BMI to guide mortality risk assessment, attention has increasingly shifted toward fat distribution, particularly abdominal obesity. Accordingly, alternative anthropometric measures such as the WHtR and ABSI have been proposed. While some studies have shown that these metrics outperform BMI in predicting all-cause mortality [15, 34, 35], and CV mortality [36], evidence regarding their association with cancer mortality remains inconsistent and highly heterogeneous across sexes and

cancer types, especially for WHtR [15]. Additionally, WHtR may disproportionately penalize shorter individuals and therefore, provide a false sense of reassurance for taller individuals with identical WC [37]. In our study, WHtR was inversely associated with all-cause mortality and exhibited an irregular association with cancer mortality.

In contrast, ABSI demonstrated a relatively stable positive association with all-cause mortality in both sexes, characterized by a steep risk elevation beginning around the median decile (Q5). However, ABSI is computationally complex [38], and its score is highly clustered around the mean, complicating the definition of clinically meaningful cutoff values for use in practice [35].

Existing evidence regarding the association between BRI and mortality outcomes remains limited and inconsistent due to its relatively recent introduction. Studies from the UK have reported a gradual increase in all-cause mortality risk across increasing BRI quartiles [39], whereas a U.S.-based study observed a U-shaped association [20]. In our analysis, the adjusted risk trajectories for BRI more closely mirrored those observed for WHtR, showing an inverse association with all-cause mortality and an irregular association with cancer mortality.

Taken together, BVI—alongside ABSI—showed a consistent positive association with both all-cause and cancer mortality in men and women, suggesting potential utility in mortality risk prediction and addressing certain limitations in conventional anthropometric indices such as BMI, WHtR, and BRI. Methodologically, BVI is computationally straightforward and displays greater numerical variability across the population continuum, which may offer more favorable clinical applicability for risk stratification than ABSI. Nevertheless, since BVI is a newly proposed indicator, further studies involving larger sample sizes and more diverse populations are warranted to establish its robustness and generalizability, and ultimate clinical utility.

Limitations

This study has several limitations that should be acknowledged. First, mortality risks were assessed by categorizing participants into sex-specific deciles for each obesity indicator rather than directly evaluating the clinical relevance of absolute values. This approach was intentionally chosen because our primary focus was to examine the overall risk trajectories of mortality across the continuum of the obesity scale, rather than to establish a definitive diagnostic threshold with specific clinical implications. Nevertheless, subsequent investigations identifying clinically meaningful cut-off points are warranted to better inform risk stratification in public health practice. Second, this study focused on evaluating epidemiological associations rather than quantifying the exact incremental predictive power of the newly proposed index. Consequently, future research incorporating formal model performance metrics—such as the C-index, net reclassification improvement (NRI), and integrated discrimination improvement (IDI)—is necessary to systematically confirm its utility in predictive clinical modeling. Third, the data utilized in this study were derived from a health check-up sub-cohort of NHIS-NSC, as information on anthropometric measurements was available only for individuals who underwent health examinations.

Consequently, the number of cause-specific deaths was relatively limited, restricting more granular sub-analyses. For example, given that obesity is a well-established risk factor for CV events, evaluating the specific relationship with CV mortality would be highly relevant. However, because individuals with pre-existing CV risk factors were excluded at the baseline recruitment stage, the number of subsequent CV events was insufficient to allow reliable statistical analysis. Future studies utilizing larger datasets with more comprehensive cause-specific mortality outcomes are needed to address this limitation. Finally, the NHIS-NSC database is not publicly available due to strict institutional and legal restrictions. Access is granted exclusively upon approval by the NHIS and is limited to on-site analysis at designated NHIS data centers or through a secure remote virtual analysis environment. Therefore, we were unable to deposit the raw dataset in an open-access repository. However, the data are available to qualified researchers who obtain official approval from the NHIS. We provided the analytical code in the Supplementary materials to enhance reproducibility (Supplementary Methods 2).

CONCLUSIONS

In this population-based study, we introduced a novel anthropometric index, the BVI, and demonstrated its potential to complement certain clinical or mathematical limitations inherent in conventional indices by showing a relatively stable positive relationship with all-cause and cancer mortality. BVI may also offer favorable practical feasibility for risk stratification within large-scale epidemiologic contexts due to its relatively straightforward geometric formulation compared to the computationally complex ABSI. These findings provide initial population-level evidence regarding the prospective utility of BVI in longitudinal risk prediction and lay the groundwork for future validation studies to establish a broader evidence base.

Declarations

CRediT authorship contribution statement

Son YE: Conceptualization, Data curation, Formal analysis, Methodology, Visualization.

Kim NS: Conceptualization, Methodology, Writing - review & editing.

Jeon GM: Conceptualization, Methodology, Writing - review & editing.

Kim CS: Conceptualization, Methodology, Writing - review & editing.

Shin DW: Validation, Writing - review & editing.

Lee HY: Funding acquisition, Validation, Methodology, Visualization, Writing - original draft.

Kim DW: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Validation, Writing - review & editing.

Role of the Funder/Sponsor

The funding organization had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Ethics approval:

The study protocol was approved by the Institutional Review Board of the College of Medicine, The Catholic University of Korea (MC24EISI0002)

Informed consent

to participate and publish: Informed consent was exempted by ethical review board due to anonymity of study population

Data Availability Statement:

Restrictions apply to the availability of these data. Data was obtained from the National Health Insurance Sharing Service and are available at https://nhiss.nhis.or.kr/ [Accessed April 12, 2026] with the permission of the National Health Insurance Service.

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Figures



Figure 1

Joint distributions of WHtR, ABSI, BRI and BVI across BMI deciles (Q1–Q10) among men.



Figure 2

Joint distributions of WHtR, ABSI, BRI and BVI across BMI deciles (Q1–Q10) among women

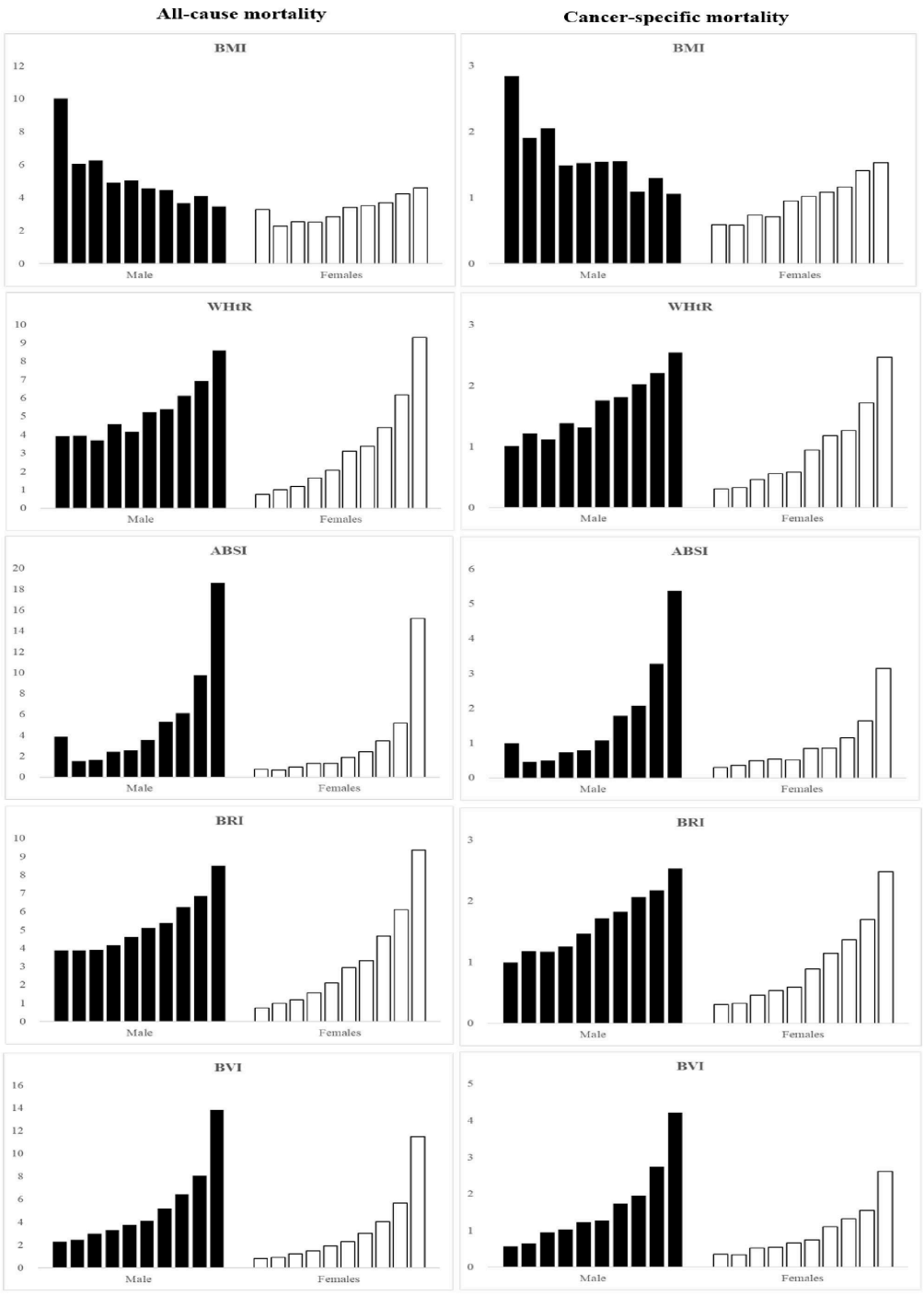


Figure 3

Unadjusted mortality according to the deciles of five obesity indicators

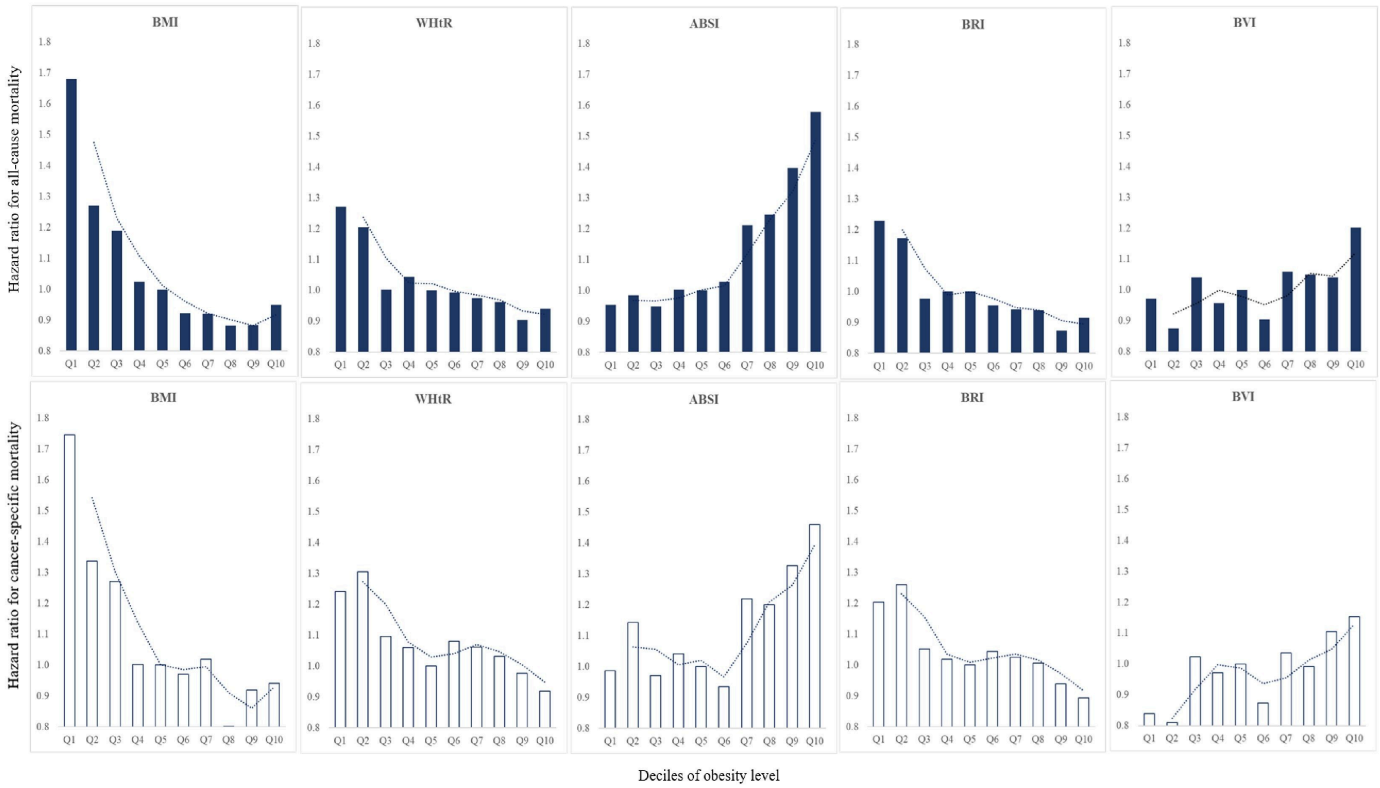


Figure 4

Association between obesity level and all-cause and cancer-specific mortality among men

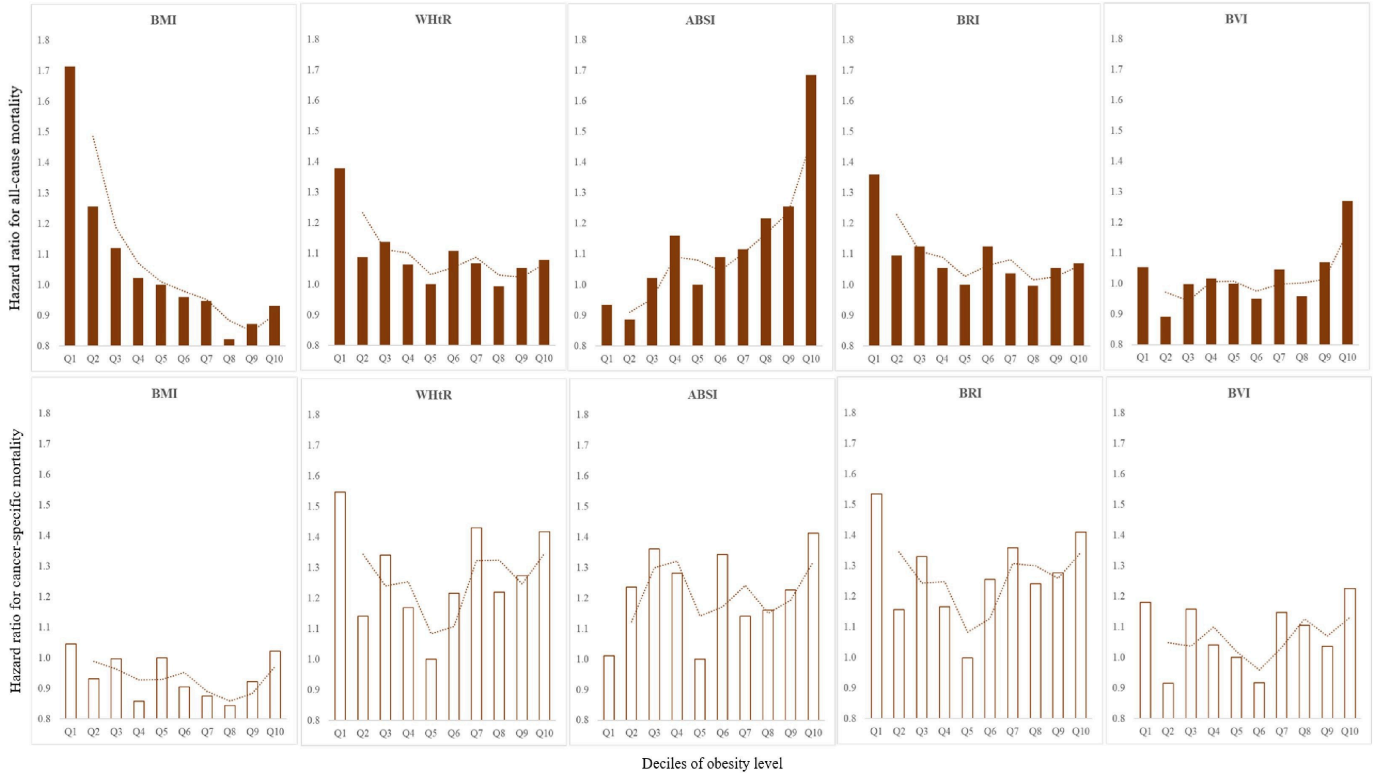


Figure 5

Association between obesity level and all-cause and cancer-specific mortality among women

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