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Association of the body roundness index with new-onset cardiovascular disease in middle-aged and older adults with and without diabetes: evidence from the China Health and Retirement Longitudinal Study

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Abstract

Background Among noncommunicable diseases, cardiovascular disease (CVD) is the leading cause of mortality and morbidity. In China, diabetes is renowned for its high incidence rate, and the body roundness index (BRI) is an emerging indicator for assessing obesity, particularly abdominal obesity. High BRI may lead to new-onset CVD events. However, the relationships between the BRI and new-onset CVD in individuals with or without diabetes remain unclear.

Methods Data for this analysis were extracted from the China Health and Retirement Longitudinal Study (CHARLS). Our research utilized a cohort that was meticulously assessed over a period from 2011 to 2018, encompassing a comprehensive follow-up of 17,708 participants. Ultimately, this study focused on a subset of 6,737 individuals aged 45 years or older. Methodological approaches include Cox regression, Kaplan-Meier survival analysis, restricted cubic splines (RCS) analysis, receiver operating characteristic (ROC) curve analysis, subgroup analysis, and mediation analysis to explore the relationships of interest.

Results This study included 6,737 participants, all of whom were above the age of 45. Our findings revealed that within this demographic group, 1,481 (22.0%) patients experienced new-onset CVD. The Kaplan-Meier survival analysis further revealed that the group characterized by non-diabetes mellitus (Non-DM) had the lowest cumulative incidence of CVD compared with the diabetes mellitus (DM) group. Multivariate Cox regression revealed that in the fully adjusted model (Model 3) (HR = 1.122, 95% CI = 1.080 to 1.167), BRI was associated with the risk of CVD in the Non-DM group during the three-wave follow-up. RCS analysis revealed a positive, linear-like dose–dependent relationship between BRI and new-onset CVD in Non-DM patients ($P = 0.007$, P for nonlinearity = 0.938). Smoking

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could affect the ability of the BRI to predict the incidence rate of CVD in the total population and in the population without diabetes (*P* interaction = 0.007). Moreover, the mediating effect of the BRI on new-onset CVD among diabetic patients was particularly pronounced in the long term, exceeding 4 years.

Conclusions Our findings demonstrate a significant association between the BRI and CVD risk in non-diabetic individuals, with diabetes influencing the incidence and risk of new-onset CVD in middle-aged and elderly Chinese populations through the BRI playing a mediating role. As an obesity indicator, the BRI provides a valuable tool for early detection and intervention of CVD.

Clinical trial number Not applicable.

Keywords Body roundness index, New-onset cardiovascular disease, Diabetes mellitus, Mediating effect, China health and retirement longitudinal study

Introduction

Cardiovascular disease (CVD) pose a serious threat to human life and health. Over the past decade, the total number of CVD-related fatalities worldwide has increased by 12.5%, with CVD accounting for one-third of all CVD-related deaths worldwide, a trend largely propelled by the demographic shift toward an aging population [1]. CVD is the leading cause of death in China, accounting for 40% of deaths in the Chinese population [2]. This increasing trend is attributed to the pervasive adoption of unhealthy lifestyles among the Chinese populace, a substantial segment of the population being exposed to CVD risk factors, and the rapid acceleration of the aging demographic [3].

Diabetes, a pervasive chronic metabolic condition, is characterized by elevated blood glucose levels, leading to significant impairments in the heart, blood vessels, kidneys, and nervous system [4]. The prevalence of diabetes in China increased from a mere 1% in the 1980s to a staggering 11% by 2013 [5]. In 2013, China was home to the largest diabetic population worldwide [5]. By 2020, nearly 30% of elderly individuals in China were estimated to be suffering from diabetes [6]. In individuals with diabetes, CVD is the predominant factor contributing to a heightened risk of premature mortality [7]. Research published in the Lancet has highlighted that elevated blood glucose levels are the primary culprit behind CVD-related fatalities in the majority of regions, underscoring the intimate link between diabetes and cardiovascular disease [8]. Furthermore, a study drawing on data from the Framingham Heart Study revealed that individuals with type 2 diabetes (T2DM) face a doubling of their risk for cardiovascular mortality compared with their non-diabetic counterparts [9]. These findings suggest that there is an association between diabetes and CVD.

The body roundness index (BRI) has emerged as a novel metric for assessing visceral fat content [10]. Numerous investigations have demonstrated a correlation between the BRI and new-onset CVD, as well as mortality rates. Research utilizing data from the National Health and Nutrition Examination Survey (NHANES) revealed a significant association between the BRI and both cardiovascular mortality and all-cause mortality among individuals with hypertension [11]. Additionally, extensive cross-sectional surveys among Chinese residents have determined that the BRI outperforms other metrics in its predictive power for CVD risk factors within the Chinese population [12, 13]. In addition to its link to CVD, research has further established a correlation between the BRI and diabetes. A study focusing on a Japanese cohort revealed that the BRI emerged as the most potent predictor of T2DM, outperforming both body mass index (BMI) and waist circumference (WC) [14]. Additionally, a subsequent retrospective analysis concluded that the initial assessment of the BRI enhances the accuracy of identifying individuals at an elevated risk for T2DM [15].

However, the ability of the BRI to predict CVD risk in individuals with and without diabetes, as well as whether the BRI mediates the association between diabetes and CVD, remains unclear. Therefore, we utilized the China Health and Retirement Longitudinal Study (CHARLS), a nationwide, population-based prospective cohort study, to investigate the ability of the BRI to predict CVD in individuals with and without diabetes. Considering the bidirectional relationship between diabetes and obesity, we also explored whether the BRI mediates the association between diabetes and CVD.

Methods

Study design and population

This research undertakes a secondary analysis of data derived from the CHARLS, a comprehensive longitudinal cohort study encompassing 450 villages, 150 counties, and 28 provinces, with a participant pool of 17,708 individuals. CHARLS, orchestrated by Peking University, employs a cluster random sampling methodology. Initiated in 2011, the study has undergone four follow-up assessments in 2013, 2015, 2018, and 2020. These assessments encompass a broad spectrum of variables, including demographic characteristics, health status and functionality, biomarkers, physical examinations, and blood test results [16, 17]. This survey research was

granted approval by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and it was conducted with the informed written consent of all participants. The study adhered to the ethical guidelines established by the national research committee for all procedures involving human subjects.

This study focused on a cohort that was assessed between 2011 and 2018, encompassing a total of 17,708 individuals in the follow-up phase. The inclusion criteria for the study were as follows: (1) aged ≥ 45 years in CHARLS 2011 and (2) had data regarding CVD and diabetes status at baseline. The exclusion criteria were as follows: (1) absence of follow-up data on CVD status; (2) lack of age information; and (3) absence of data regarding height and WC measurements. Our study ultimately included 6,737 participants, all of whom were free from CVD at baseline and had complete information on their CVD and diabetes status throughout the follow-up period. The detailed selection process is depicted in Fig. 1.

Outcome indicators

Diabetes

In the questionnaire, participants were asked "Have you been diagnosed with diabetes or high blood sugar by a doctor?". If the participants answered "yes", they were considered to have diabetes mellitus (DM). DM was also defined as fasting blood glucose (FBG) ≥ 126 mg/dl or glycated hemoglobin (HbA1c) ≥ 6.5% and/or the use of hypoglycemic agents [18]. The participants were divided into a non-diabetes mellitus (Non-DM) group and a DM group [19].

New-onset CVD

CVD events include heart disease and stroke. Like in previous studies, CVD events were assessed by the following questions: "Have you been told by a doctor that you have been diagnosed with heart disease/stroke?" and "Are you now undergoing any of the following treatments (taking Chinese traditional medicine/taking Western modern medicine/other treatments/none of the above) to treat heart disease/stroke or its complications?". Participants who reported "yes" for receiving a diagnosis of heart disease/stroke from a doctor or those who indicated specific treatment for heart disease/stroke were defined as new-onset CVD [20]. Additionally, we utilized biomarkers (e.g., blood lipids, blood pressure, and glycated hemoglobin [HbA1c]) to indirectly assess cardiovascular risk, thereby reducing the reliance on self-reported data. The time of new-onset CVD during follow-up was recorded as the answer to the question "When was the condition first diagnosed or known by yourself?" [19].

BRI

The BRI is a new body type evaluation index that evaluates human body type by measuring height and WC. The calculation formula of the BRI is as follows: $\mathrm{BRI} = 364.2 - 365.5 \times \left[\left(1 - \left(\mathrm{WC}/2\pi\right)^2/\left(0.5 \times \text{ height}\right)^2\right)\right]^{1/2}$. WC was determined via a nonelastic measuring tape and recorded to the nearest 0.1 centimeters (cm). Height was similarly measured with a stadiometer, with precision to the nearest 0.1 cm.

Covariates

The inclusion of these covariates was based on prior studies and clinical experience. At baseline, skilled interviewers gathered data on sociodemographic status and health-related factors through a structured questionnaire. The sociodemographic variables included age, sex, and educational attainment and were categorized as elementary school and below, secondary school, and college and above. The health-related factors assessed included height, weight, BMI, WC, cardiometabolic index (CMI), hypertension (HTN), dyslipidemia, smoking status, alcohol consumption, physical activity levels, and biomarkers. Among these covariates, HTN and dyslipidemia were identified on the basis of self-reported physician diagnoses and were ascertained from baseline data. HTN is defined as a systolic blood pressure ≥ 140 mmHg or a diastolic blood pressure ≥ 90 mmHg. Dyslipidemia can be diagnosed if one or more of the following fasting venous plasma indicators are met: total cholesterol (TC) ≥ 6.2 mmol/L; low-density lipoprotein cholesterol (LDL-C) ≥ 4.1 mmol/L; triglycerides (TG) ≥ 2.3 mmol/L; and high-density lipoprotein cholesterol (HDL-C) < 1.0 mmol/L.

Furthermore, the relevant index is calculated:

$$\mathrm{BMI} = \text{weight (kg)} / \text{height } \left(m^2\right),$$

$$\mathrm{CMI} = \mathrm{TG(mmol/L)}/\mathrm{HDL-C\ (mmol/L)} \times \mathrm{WHtR}.$$

Statistical analyses

Baseline data are presented via various statistical methods. Quantitative data that were normally distributed are expressed as the mean ± standard deviation (SD) and were compared via a test. Categorical data are depicted as percentages and were compared via the chi-square test. For this study, the population was stratified into two distinct groups on the basis of the presence of diabetes mellitus: Non-DM and DM. The Kaplan-Meier curve and log-rank test were used to compare the cumulative incidence of events across these groups. Cox regression analysis was conducted to evaluate whether BRI

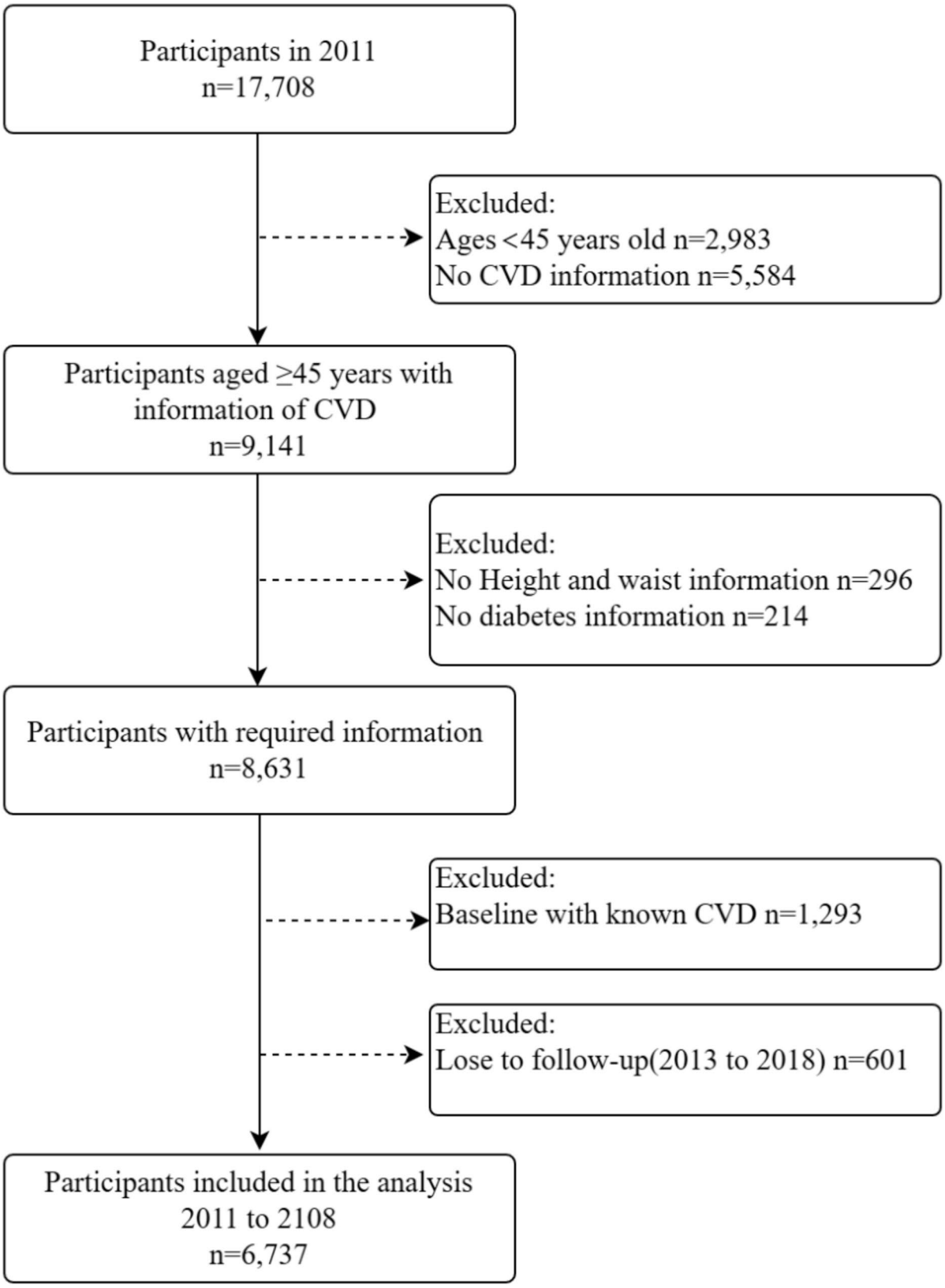

Fig. 1 The research participants had information on age, height, waist circumference, diabetes status, and cardiovascular disease. Additionally, they had no history of cardiovascular disease at baseline and were not lost to follow-up at the three subsequent follow-up visits. Ultimately, 6,737 researchers were included in the study

was associated with new-onset CVD during the follow-up period. Restricted cubic splines (RCS) were used to analyze the potential nonlinear relationship between BRI and new-onset CVD. The performance of the BRI was assessed via receiver operating characteristic (ROC) curves. Stratified analysis was used to evaluate whether the specified subgroups altered the association between the BRI and the incidence rate of CVD in individuals with and without diabetes. Ultimately, a mediation effect analysis was conducted to elucidate the relationships among diabetes, the BRI, and the risk of new-onset CVD [19]. All calculations were performed via R (version 4.2.1).

Table 1 Characteristics of the baseline population in 2011, grouped by history of diabetes

Characteristics	All	Non-DM	DM	*P*
n	6737	6434	303	
Age, years	58.4 ± 8.8	58.4 ± 8.8	58.8 ± 8.0	0.458
Male, n(%)	3088(45.9)	2975(46.2)	113(37.3)	0.002
Height, m	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	0.561
Weight, kg	58.8 ± 11.5	58.5 ± 11.3	63.8 ± 14.1	< 0.001
BMI, kg/m^2	23.4 ± 4.1	23.4 ± 4.0	25.4 ± 5.1	< 0.001
Waist, cm	85.1 ± 9.9	84.8 ± 9.8	90.8 ± 9.9	< 0.001
BRI	4.2 ± 1.4	4.2 ± 1.4	4.9 ± 1.4	< 0.001
CMI	1.2 ± 2.2	1.2 ± 2.1	1.9 ± 3.3	< 0.001
Education level, n(%)				
Elementary school or below	6087(90.4)	5821(90.5)	266(87.8)	0.282
Secondary school	570(8.5)	537(8.3)	33(10.9)	
College and above	77(1.1)	73(1.1)	4(1.3)	
History of disease, n(%)				
HTN	1391(20.7)	1253(19.5)	138(45.5)	< 0.001
Dyslipidemia	475(7.2)	382(5.9)	93(30.7)	< 0.001
CVD at follow-up	1481(22.0)	1369(21.3)	112(37)	< 0.001
Personal history, n(%)				
Smoking	2577(38.3)	2483(38.6)	94(31)	0.008
Drinking	1747(25.9)	1692(26.3)	55(18.2)	0.002
Physical activity	2589(38.4)	2476(38.5)	113(37.3)	0.676
Biomarkers				
WBC(×10^9/L)	6.3 ± 1.9	6.2 ± 1.9	6.5 ± 1.9	0.030
Plt (×10^9/L)	212.0 ± 73.0	212.0 ± 73.2	211.4 ± 70.1	0.893
FBG (mg/dL)	109.5 ± 35.2	106.8 ± 28.4	165.2 ± 84.7	< 0.001
Cr (μmol/L)	0.8 ± 0.2	0.8 ± 0.2	0.8 ± 0.2	0.863
TC (mg/dL)	194.2 ± 38.7	194.0 ± 38.7	197.9 ± 39.1	0.084
TG (mg/dL)	133.0 ± 111.4	131.4 ± 109.5	167.3 ± 142.1	< 0.001
HDL-C (mg/dL)	51.5 ± 15.4	51.8 ± 15.4	46.2 ± 15.4	< 0.001
LDL-C (mg/dL)	116.7 ± 34.7	116.6 ± 34.6	118.3 ± 36.2	0.398
CRP (mg/L)	2.4 ± 6.5	2.4 ± 6.5	2.8 ± 5.3	0.276
HbA1c (%)	5.3 ± 0.8	5.2 ± 0.6	6.6 ± 1.8	< 0.001
HCT (%)	41.5 ± 6.3	41.5 ± 6.3	41.3 ± 5.8	0.521
Hb (g/L)	14.4 ± 2.2	14.4 ± 2.2	14.2 ± 2.0	0.279

BMI: body mass index; BRI: body roundness index; CMI: cardiometabolic index; HTN: hypertension; CVD: cardiovascular disease; WBC: white blood cell; Plt: platelets; FBG: fasting plasma glucose; Cr: creatinine; TC: total cholesterol; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; CRP: C-reactive protein; HbA1c: glycated hemoglobin; HCT: hematocrit; Hb: hemoglobin

Results

Characteristics of the baseline population

The baseline data were compared among groups stratified by the presence of a history of diabetes at the beginning of the study. A total of 6,737 participants were included in the final analysis, with 303 (4.5%) individuals having diabetes. Compared with the DM group, the Non-DM group had a greater percentage of males (46.2%) and presented lower values for weight, BMI, WC, BRI, and CMI. Furthermore, the Non-DM group had reduced incidence rates of HTN and dyslipidemia. The Non-DM group also presented with lower levels of FBG, TG, HDL-C, and HbA1c. Significant differences in the incidence of new-onset CVD during the follow-up period were observed between the two groups ($P < 0.05$) (Table 1). The population excluded from this study due to missing data had their missing data imputed for baseline data analysis, grouped by the presence of a history of diabetes. A total of 6,695 individuals were included in the analysis, of whom 375 (5.6%) had diabetes. Similar to the included population, the Non-DM group had a greater percentage of males (48.9%) and presented lower values for weight, BMI, WC, BRI, and CMI than did the DM group. These findings indicate that our analysis of the included population is robust (Supplementary Table S1).

Risk factors for new-onset CVD in three-wave follow-up

During the three follow-up periods, a total of 1,481 new-onset CVD events were recorded. The cumulative incidence of new-onset CVD was 6.84% at the first follow-up, 13.94% at the second follow-up, and 21.98% at the third follow-up. Additionally, at each follow-up, the BRI values in the Non-CVD group were significantly lower than those in the cumulative new-onset CVD group ($P < 0.05$). Other factors correlated with new-onset CVD included age, sex, BMI, WC, HTN, dyslipidemia, alcohol consumption, platelets (Plt), TC, LDL-C, and HbA1c. Notably, while many indicators were not significantly different in the short term (2 years), significant differences emerged in the long term (4 years and beyond) between the non-CVD group and the new-onset CVD group (Supplementary Table S2).

Survival analysis

The Kaplan-Meier curve revealed that the Non-DM group had the lowest cumulative incidence, whereas the DM group had the highest cumulative incidence, with statistically significant differences between the groups

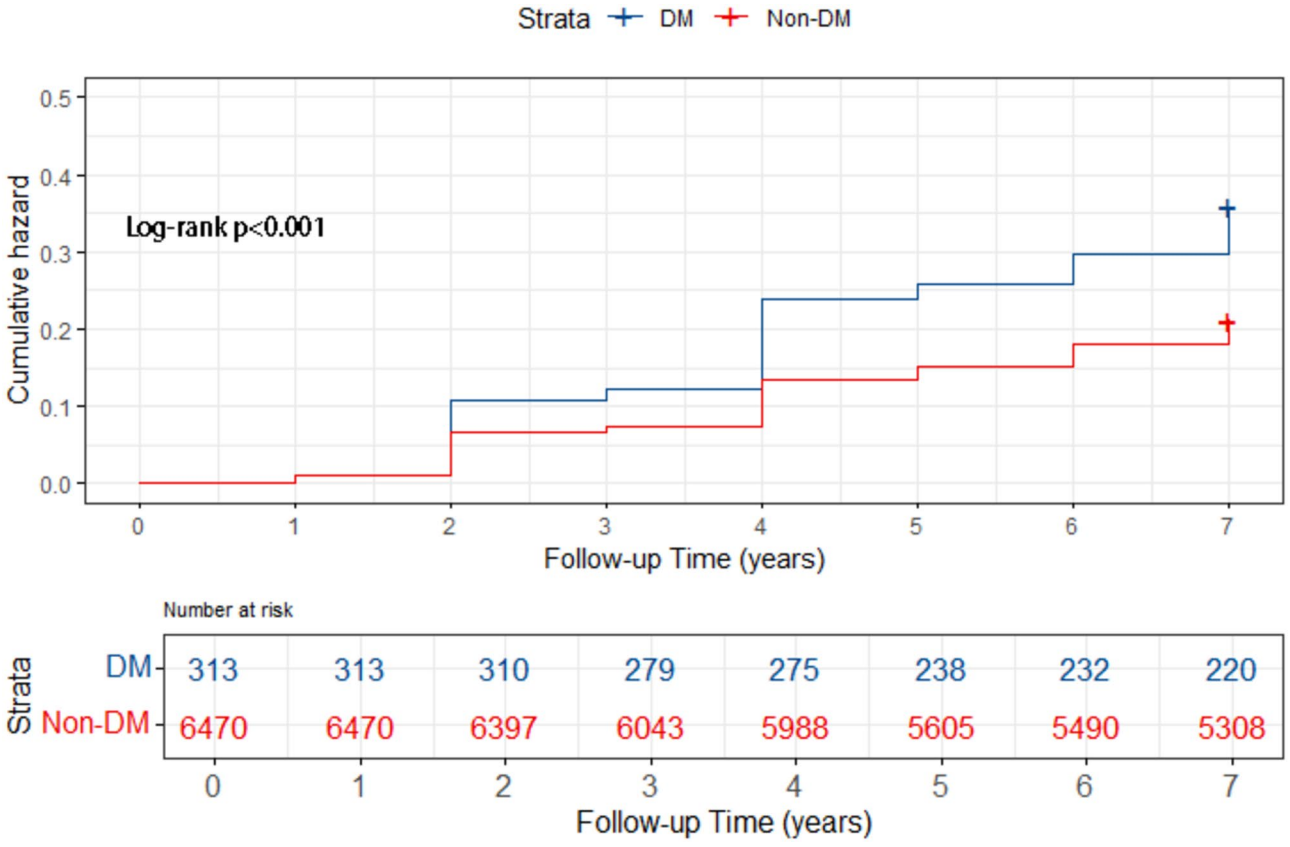

Fig. 2 Kaplan-Meier curves for the cumulative incidence of CVD in the two groups. Among the two groups, non-diabetes mellitus (Non-DM) and diabetes mellitus (DM), the cumulative incidence was significantly different according to the log-rank test ($P < 0.001$)

Table 2 Cox regression analysis of the association between the BRI and CVD in individuals with and without diabetes

Model	Model 1		Model 2		Model 3	
Group	HR(95%CI)	*P*	HR(95%CI)	*P*	HR(95%CI)	*P*
Wave1						
DM	1.241(0.989,1.557)	0.062	1.172(0.927,1.048)	0.184	1.182(0.927,1.506)	0.177
Non-DM	1.212(1.138,1.290)	< 0.001	1.170(1.094,1.251)	< 0.001	1.134(1.059,1.214)	< 0.001
Wave2						
DM	1.140(0.973,1.334)	0.105	1.109(0.942,1.307)	0.214	1.112(0.938,1.318)	0.223
Non-DM	1.172(1.120,1.226)	< 0.001	1.141(1.087,1.198)	< 0.001	1.084(1.032,1.139)	0.001
Wave3						
DM	1.240(1.091,1.409)	0.001	1.226(1.071,1.403)	0.003	1.169(1.015,1.345)	0.030
Non-DM	1.192(1.150,1.235)	< 0.001	1.167(1.123,1.212)	< 0.001	1.122(1.080,1.167)	< 0.001

The population was divided into DM and Non-DM groups for Cox analysis to examine the association between the BRI and new-onset CVD

Model 1: unadjusted; Model 2: adjusted for covariates including age, sex, and education level; Model 3: adjusted for covariates including age, sex, education level, BMI, CMI, HTN, dyslipidemia, smoking, drinking, physical activity, WBC, Plt, FBG, Cr, TC, TG, HDL-C, LDL-C, CRP, HbA1, HCT, and Hb

($P < 0.001$) (Fig. 2). Multivariate Cox regression models were created (Table 2). In the adjusted model (Model 2) (HR = 1.167, 95% CI = 1.123 to 1.212) and fully adjusted model (Model 3) (HR = 1.122, 95% CI = 1.080 to 1.167), the BRI was associated with the risk of CVD in the Non-DM group during the three-wave follow-up. However, in the DM group, BRI was associated with the risk of CVD in the adjusted model (Model 2) (HR = 1.226, 95% CI = 1.071 to 1.403) and fully adjusted model (Model 3) (HR = 1.169, 95% CI = 1.015 to 1.345)) only at the third follow-up.

Restricted cubic spine analysis and ROC curve

The RCS analysis results are shown in Fig. 3A positive, linear-like dose–dependent relationship between the BRI and new-onset CVD was observed in Non-DM patients ($P = 0.007$, P for nonlinearity = 0.938; Fig. 3E-F). However, in the DM group, after adjusting for covariates,

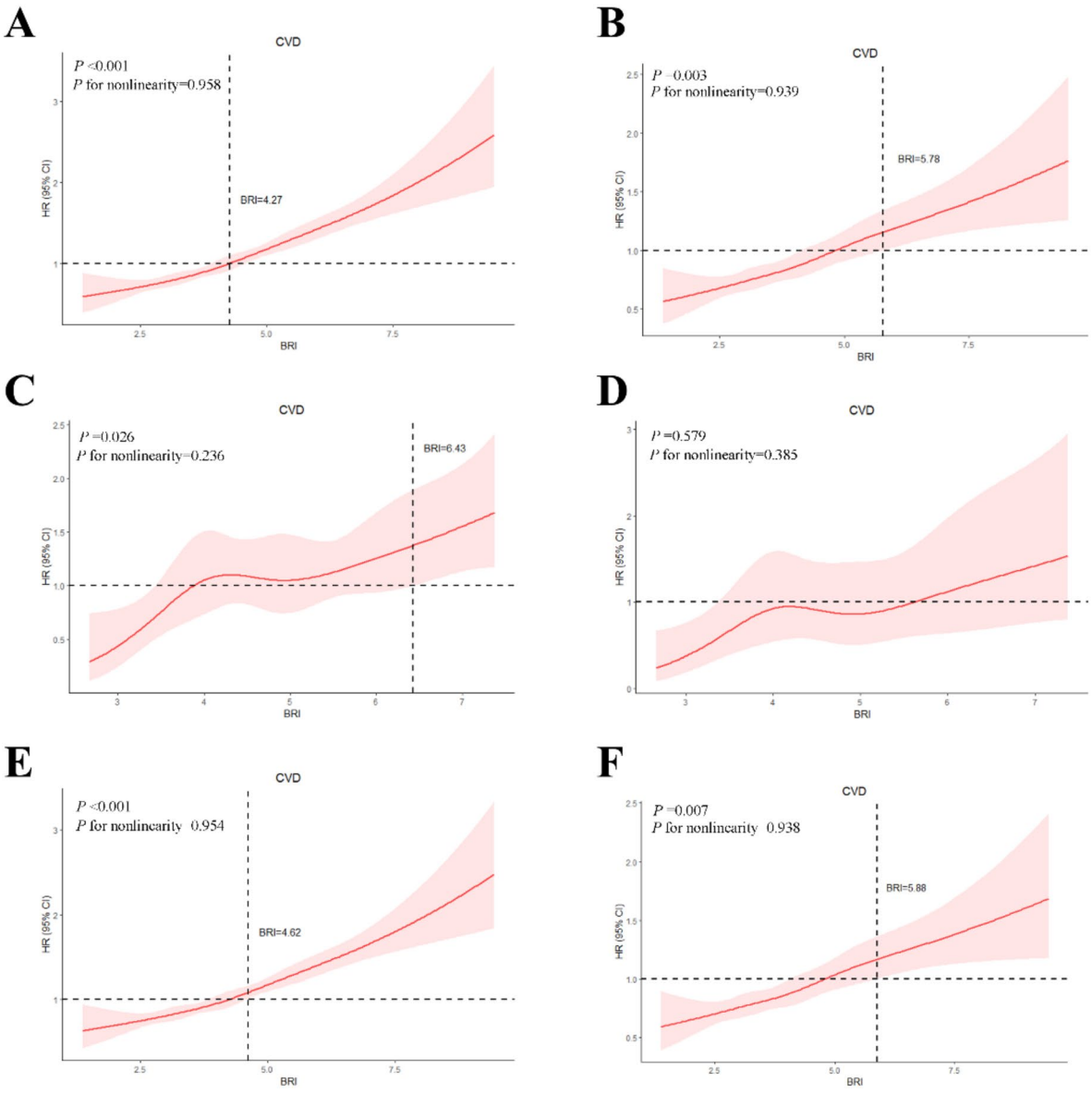

Fig. 3 Restricted cubic spine (RCS) analyses of the association between the BRI and new-onset CVD. (**A**) and (**B**) RCS analysis of the whole population. (**C**) and (**D**) RCS analysis of the diabetic population. (**E**) and (**F**) RCS analysis of the non-diabetic population. (**A**), (**C**) and (**E**) were not adjusted for covariates. (**B**), (**D**) and (**F**) adjusted for covariates, including age, sex, education level, BMI, CMI, HTN, dyslipidemia, smoking, drinking, physical activity, WBC, Plt, FBG, Cr, TC, TG, HDL-C, LDL-C, CRP, HbA1, HCT, and Hb

no significant difference was found in the dose–dependent relationship between the BRI and new-onset CVD ($P = 0.579$, P for nonlinearity = 0.385; Fig. 3C-D). This may be due to the complex factors of hyperglycemia and insulin resistance in the diabetic population. The performance of the BRI was assessed via ROC curve (Supplementary Fig. S1).

Subgroup and interaction analysis

Stratified analysis was used to evaluate whether the specified subgroups altered the association between the BRI and the incidence rate of new-onset CVD. These covariates were statistically tested for interactive effects. The association between the BRI and CVD incidence appeared to be attenuated in individuals with diabetes. The ability of the BRI to predict the incidence rate of CVD was affected only by the smoking subgroup in the population without diabetes (P interaction = 0.007). However, in the population with diabetes, smoking did not affect the predictive performance of the BRI (Figs. 4–5). Overall, the association between the BRI and new-onset

CVD is robust across different covariate subgroups in Non-DM individuals.

Mediating effect of the BRI between diabetes and new-onset CVD

Mediation analysis was conducted to investigate the relationships among diabetes, the BRI, and new-onset CVD. In Model 1, without adjusting for covariates, the mediating values of the BRI at the three follow-ups were 27.27%, 17.46%, and 20.52%, respectively. In Model 2, after controlling for all covariates, the mediating values of the BRI at the three follow-ups were 21.03%, 13.25%, and 16.88%, respectively. Combining the results from both models, the mediating effect of the BRI between new-onset CVD and diabetes was found to be more significant in the long term (≥4 years) (Fig. 6). The specific mediating effects of the BRI between diabetes and new-onset CVD are detailed in Supplementary Table S4.

Discussion

In our study of middle-aged and older adults (≥45 years) in China, we observed a significant positive association between the BRI and new-onset CVD, particularly among Non-DM individuals. Our findings suggest that the BRI may serve as a valuable predictor of new-onset CVD in Non-DM individuals. Furthermore, a linear-like dose–response relationship between the BRI and CVD risk was evident in Non-DM individuals, whereas no significant linear-like association was observed in DM individuals. We used subgroup analysis and found that the association between the BRI and new-onset CVD is robust across different covariate subgroups in Non-DM individuals. Furthermore, an interaction exists between smoking and the BRI in Non-DM individuals, and there is a mediating effect of the BRI between diabetes and CVD.

Previous studies have investigated the association between the BRI and CVD incidence, identifying the BRI as a predictive factor for CVD onset [10, 21]. Notably, comparative analyses of traditional anthropometric

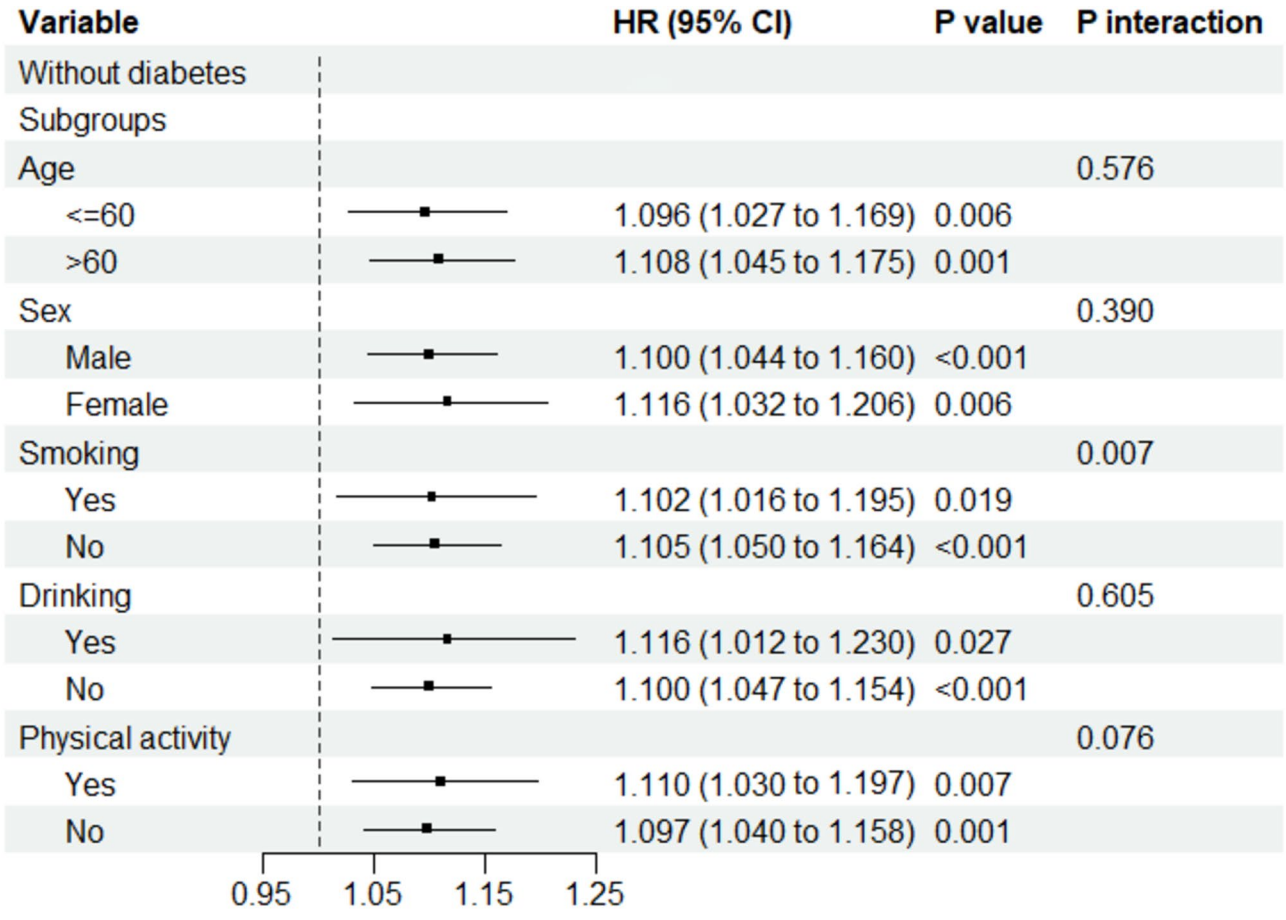

Fig. 4 Subgroup and interaction analyses on the association of the BRI and new-onset CVD in the population without diabetes. *P*-interaction refers to the interaction effect of other covariates on the influence of the BRI on new-onset CVD, which is tested by adding interaction terms to the regression model. Adjusted covariates included age, sex, education level, BMI, CMI, HTN, dyslipidemia, smoking, drinking, physical activity, WBC, Plt, FBG, Cr, TC, TG, HDL-C, LDL-C, CRP, HbA1, HCT, and Hb. HR: hazard ratio; CI: confidence interval

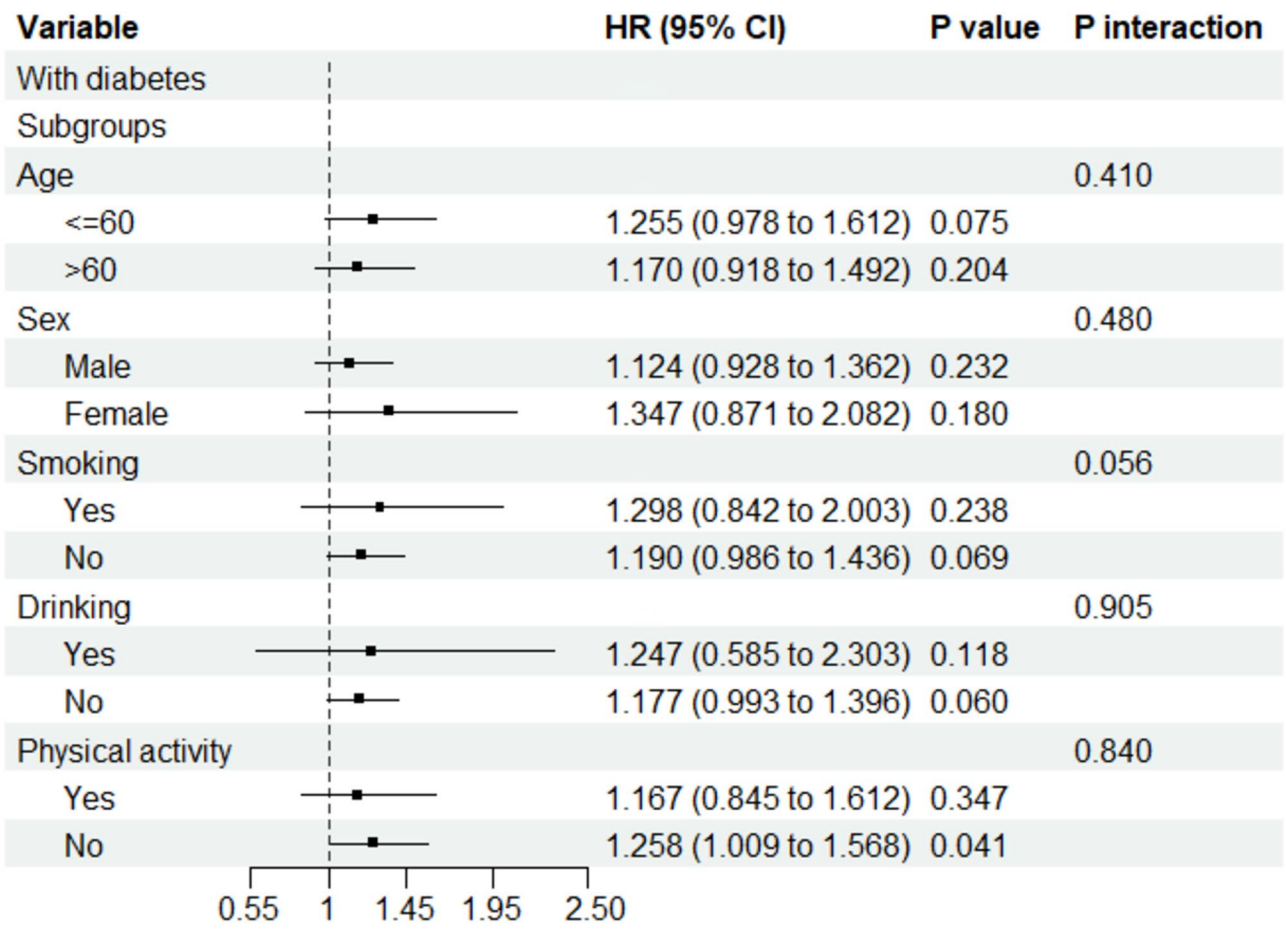

Fig. 5 Subgroup and interaction analyses on the association of the BRI and new-onset CVD in the population with diabetes. *P*-interaction refers to the interaction effect of other covariates on the influence of the BRI on CVD, which is tested by adding interaction terms to the regression model. Adjusted covariates included age, sex, education level, BMI, CMI, HTN, dyslipidemia, smoking, drinking, physical activity, WBC, Plt, FBG, Cr, TC, TG, HDL-C, LDL-C, CRP, HbA1, HCT, and Hb. HR: hazard ratio; CI: confidence interval

indices (e.g., BMI and WC) demonstrated the superiority of the BRI in predicting both CVD and diabetes [22]. Furthermore, the coexistence of sarcopenia and an elevated BRI was associated with increased CVD risk [23]. However, these investigations were restricted to specific populations (e.g., hypertensive individuals) with a maximum follow-up duration of 3 years, which is relatively short. Crucially, they failed to examine differential associations between the BRI and CVD in non-diabetic versus diabetic populations, nor did they explore BRI's potential mediating role in diabetes and CVD. Therefore, we used a Chinese cohort study with a longer duration to investigate the association between the BRI and the incidence of CVD in individuals with and without diabetes and further analyzed the mediating role of the BRI between diabetes and CVD. After 7 years of follow-up, we found that in non-diabetic individuals, the BRI is a valuable predictor of CVD, and there is a linear relationship between the BRI and CVD. The BRI acts as a mediator in the association between diabetes and CVD.

As a new indicator of abdominal obesity, the possible mechanism linking BRI and CVD is as follows: Firstly, obese individuals have increased total blood volume, stroke volume, and cardiac output, which leads to increased cardiovascular work and subsequently causes left ventricular dilatation and hypertrophy, ultimately leading to heart dysfunction [24, 25]. Secondly, obesity causes insulin resistance and glucose intolerance, leading to atherosclerotic dyslipidemia and inflammatory responses [26, 27]. Finally, steatosis increases cardiac toxicity, ultimately leading to cardiac structural remodeling [25]. Thus, monitoring the BRI and incidence of diabetes plays an important role in preventing new-onset CVD in the clinic. However, the association between the BRI and CVD was not significant among individuals with diabetes, possibly because of the overproduction of reactive oxygen species (ROS) [28], the activation of nitric oxide synthase driven by insulin resistance [29], and the deposition of hyperglycemia-induced advanced glycation end products (AGEs) [30, 31].

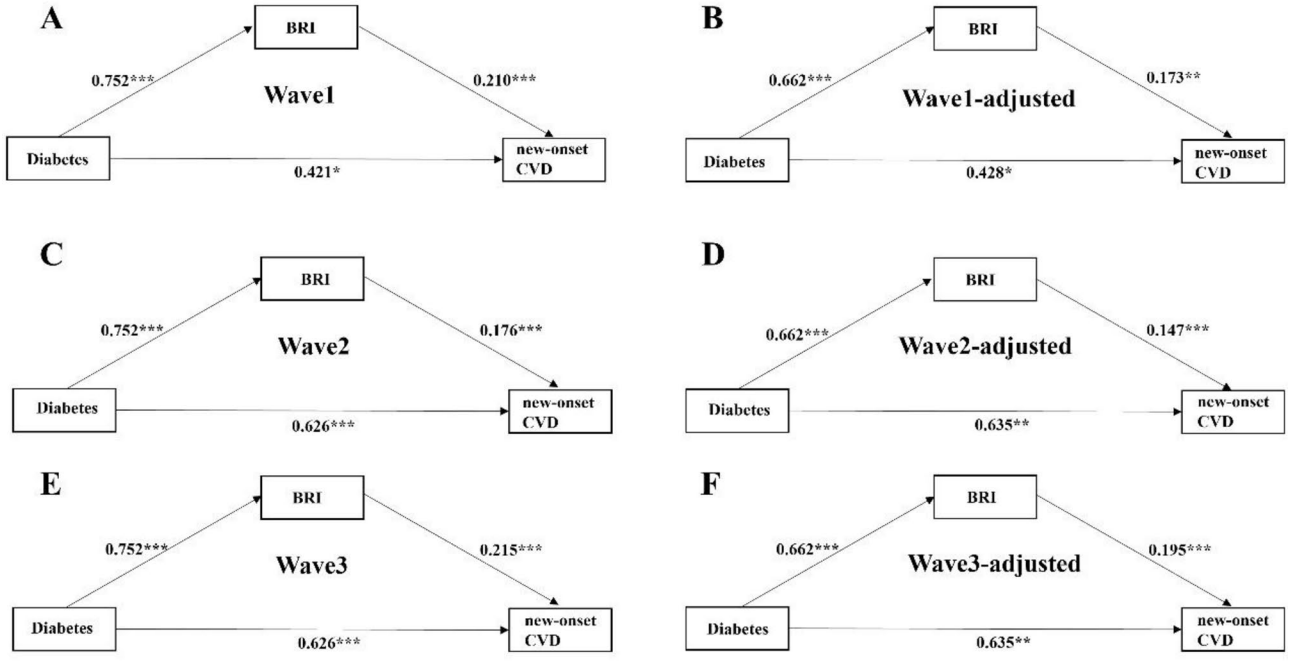

Fig. 6 The mediating effect of the BRI between diabetes and new-onset CVD in three waves of follow-up. (**A**), (**C**) and (**E**): no adjustments. (**B**), (**D**) and (**F**): adjusted covariates included age, sex, education level, BMI, CMI, HTN, dyslipidemia, smoking, drinking, physical activity, WBC, Plt, FBG, Cr, TC, TG, HDL-C, LDL-C, CRP, HbA1, HCT, and Hb. BRI: body roundness index. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Furthermore, in the subgroup analysis, we found that smoking could affect the ability of the BRI to predict the incidence rate of CVD in the population without diabetes. Although the specific mechanisms underlying the interaction between smoking and the BRI in causing CVD have not been fully elucidated, studies have shown that smoking can lead to weight gain and visceral fat accumulation [32]. As a result, smoking is a risk factor for metabolic syndrome and CVD [33]. Additionally, smoking or nicotine can affect the differentiation of fat cells, lipolysis, and the secretory properties of adipose tissue. The resulting abnormalities in adipose tissue may accelerate atherosclerosis, ultimately leading to CVD [34]. Moreover, smoking activates inflammation-related signaling pathways, thereby contributing to CVD [35]. Obesity, on the other hand, can lead to a state of low-grade inflammation in the body, which in turn promotes the pathogenesis of CVD [36]. Therefore, smoking and the BRI may interact to promote the occurrence of CVD through the aforementioned pathways in the non-diabetic population. Diabetic patients usually have increased levels of inflammation and oxidative stress, which may mask the interaction between smoking and the BRI.

This study has several strengths. The key strength of our study lies in the enhanced robustness afforded by the large-scale sample derived from the CHARLS database (2011–2018), ensuring the generalizability of our findings to the Chinese middle-aged and older adult population. We conducted detailed analyses of linear associations via RCS analysis. Furthermore, stratified and interaction analyses were performed, adjusting for potential confounders, including age, sex, smoking, drinking, and physical activity, thereby enhancing the statistical robustness of the results.

This study has several limitations. First, owing to data resource limitations, the determination of CVD onset time relies on self-reports, which may lead to recall bias resulting from inaccuracies in respondents' memory or cognitive differences that cause underreporting or overreporting. This bias may be nondifferential, potentially underestimating the association between diabetes and CVD. To mitigate the impact of recall bias, future studies should incorporate objective data to further validate the findings of this research. Second, although our analysis included some covariates, limitations in the database prevented the inclusion of variables such as dietary habits. This omission may introduce residual confounding, potentially leading to overestimation or underestimation of the observed associations. Specifically, if dietary habits are correlated with both diabetes and CVD, their absence could bias the effect estimates and reduce the validity of causal inferences. Future studies should use supplementary datasets to address this limitation.

Conclusions

Our findings demonstrate a significant association between the BRI and CVD risk in non-diabetic individuals, with diabetes influencing the incidence and risk

of new-onset CVD in middle-aged and elderly Chinese populations through the BRI playing a mediating role. As an obesity indicator, the BRI provides a valuable tool for early detection and intervention of CVD.

Abbreviations

CVD	Cardiovascular disease
T2DM	Type 2 diabetes
BRI	Body roundness index
NHANES	National Health and Nutrition Examination Survey
WC	Waist circumference
BMI	Body mass index
WC	Waist circumference
CHARLS	China Health and Retirement Longitudinal Study
DM	Diabetes mellitus
Non-DM	Non-diabetes mellitus
FBG	Fasting blood glucose
HbA1c	Glycated hemoglobin
CMI	Cardiometabolic index
HTN	Hypertension
TC	Total cholesterol
LDL-C	Low-density lipoprotein cholesterol
TG	Triglycerides
HDL-C	High-density lipoprotein cholesterol
SD	Standard deviation
RCS	Restricted cubic splines
ROC	Receiver operating characteristic
Plt	Platelets
HR	Hazard ratio
CI	Confidence interval
ROS	Reactive oxygen species
NO	Nitric oxide
AGEs	Advanced glycation end products
WBC	White blood cell
Cr	Creatinine
CRP	C-reactive protein
HCT	Hematocrit
Hb	Hemoglobin
AUC	Area under the curve

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13098-025-01705-9.

Supplementary Material 1

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Author contributions

Y.L.K., Q.L., and Q.W. designed the manuscript. Y.L.K. wrote the manuscript. Y.L.K. drew the figures and compiled the table. Q.Z. and Q.L. revised the manuscript. These authors contributed equally to this work. All authors have read and approved the article.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The CHARLS survey was granted approval by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and it was conducted with the informed written consent of all participants. The study adhered to the ethical guidelines established by the national research committee for all procedures involving human subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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