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ORIGINAL RESEARCH

# Body Roundness Index Trajectories and the Incidence of Cardiovascular Disease: Evidence From the China Health and Retirement Longitudinal Study

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**BACKGROUND:** Several previous cross-sectional studies suggested that body roundness index (BRI) may be associated with cardiovascular disease (CVD). However, the association should be further validated. Our study aimed to assess the association of the BRI trajectories with CVD among middle-aged and older Chinese people in a longitudinal cohort.

**METHODS AND RESULTS:** A total of 9935 participants from the CHARLS (China Health and Retirement Longitudinal Study) with repeated BRI measurements from 2011 to 2016 were included. The BRI trajectories were identified by group-based trajectory modeling. The primary outcome was incident CVD (stroke or cardiac events), which occurred in 2017 to 2020. Cox proportional hazards regression models were used to examine the association of BRI trajectories with CVD risk. Participants were divided into 3 BRI trajectories, named the low-stable BRI trajectory, moderate-stable BRI trajectory and high-stable BRI trajectory, accounting for 49.81%, 42.35%, and 7.84% of the study population, respectively. Compared with participants in the low-stable BRI trajectory group, those in the moderate-stable and high-stable BRI trajectory groups had an increased risk of CVD, with multivariable adjusted hazard ratios of 1.22 (95% CI, 1.09–1.37) and 1.55 (95% CI, 1.26–1.90), respectively. Furthermore, simultaneously adding the BRI trajectory to the conventional risk model improved CVD risk reclassification (all $P<0.05$).

**CONCLUSIONS:** A higher BRI trajectory was associated with an increased risk of CVD. The BRI can be included as a predictive factor for CVD incidence.

**Key Words:** body roundness index ■ cardiovascular disease ■ CHARLS ■ group-based trajectory modeling

Cardiovascular disease (CVD) is the leading cause of global death and a major contributor to health loss worldwide. The number of deaths due to CVD worldwide increased from 12.4 million in 1990 to 19.8 million in 2022. The prevalence of CVD is expected to increase, especially for middle-aged and older adults, which also places a substantial economic burden on society.[1,2] In China, CVD death increased by 58.5% from 1990 to 2016. In addition, CVD was the leading cause of death in China, accounting for 40% of deaths in 2010.[1,3] Obesity is a major modifiable risk factor for CVD.[4] Compared with general obesity represented by the body mass index, abdominal obesity has been proposed to be a much stronger risk factor for CVD.[5,6]

The body roundness index (BRI) is an abdominal obesity-related anthropometric index proposed by

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## CLINICAL PERSPECTIVE

### What Is New?

- This is the first large well-designed prospective study to evaluate the body roundness index trajectories and the incidence of cardiovascular disease among middle-aged and older Chinese people.
- Higher body roundness index trajectories were associated with an increased risk of cardiovascular disease.

### What Are the Clinical Implications?

- The longitudinal trajectory of the body roundness index could be used as a novel indicator of cardiovascular disease risk, which provides a new possibility for cardiovascular disease prevention.

### Nonstandard Abbreviations and Acronyms

| | |
|---|---|
| **BRI** | body roundness index |
| **CHARLS** | China Health and Retirement Longitudinal Study |
| **IDI** | integrated discrimination improvement |
| **NRI** | net reclassification improvement |
| **WC** | waist circumference |

Thomas in 2013 that combines waist circumference (WC) and height to describe a person's body shape and better reflects the proportion of body fat and visceral fat than traditional indices such as body mass index, WC, and hip circumference.[7] Previous cross-sectional studies have shown that the BRI can significantly determine the presence of metabolic syndrome and insulin resistance.[8] Moreover, BRI is a valuable predictor of CVD risk in men and women in the Chinese population.[8,9] In addition, a U-shaped relationship between BRI and CVD death as well as all-cause death had been observed.[10] Compared with cross-sectional studies, longitudinal studies are more valuable for demonstrating the relationship between pathogenesis and outcome. Longitudinal studies involve repeatedly collecting measurements of variables and discussing the relationships between dynamically changing factors and disease.[11] Group-based trajectory modeling is a common method for describing the course of a measured variable over time. To our knowledge, studies on the association of longitudinal BRI trajectories with CVD morbidity are limited, especially among middle-aged and older populations. Recent studies based on a longitudinal trajectory model found that higher levels of BRI over time were statistically related to a higher risk of CVD and death.[12,13] However, these studies have been conducted in local areas or specific populations without a multicenter design. There were no studies focused on BRI trajectories and CVD incidence in the Chinese national population. The CHARLS (China Health and Retirement Longitudinal Study) is a nationally representative study of middle-aged and older adults. Therefore, this study aimed to further explore the relationship between BRI trajectories and CVD incidence using data from CHARLS.

## METHODS

### Data Availability Statement

All data are publicly available, on research approval access, from CHARLS on the website (http://charls.pku.edu.cn/en).

### Study Participants

The study participants were middle-aged and older adults from the CHARLS, an ongoing, nationally representative, prospective, longitudinal, population-based study in China. Details of the study design have been published elsewhere.[14] Briefly, 17 708 participants from 10 257 households recruited from 28 provinces within China were included at baseline (2011–2012, wave 1) using a multistage stratified probability proportional-to-size sampling technique. CHARLS participants were followed up every 2 years using a face-to-face computer-assisted personal interview. All physicians who participated in the study were trained at Peking University by CHARLS staff members.[14] Four subsequent follow-ups were carried out in 2013 to 2014 (wave 2), 2015 to 2016 (wave 3), 2017 to 2018 (wave 4), and 2019 to 2020 (wave 5) among survivors. Ethical approval for all the CHARLS waves was granted from the Institutional Review Board at Peking University. The Institutional Review Board approval number for the main household survey, including anthropometrics, is IRB00001052-11015; the IRB approval number for biomarker collection was IRB00001052-11014.

In our study, participants were excluded if they had missing survey information on the BRI at baseline (ie, 2011–2012) or if they had known physician-diagnosed CVD (eg, stroke or cardiac events) during 2011 to 2015. We first included 16 931 participants aged ≥45 years and excluded 3807 participants who had missing data points for the BRI. A total of 2257 participants who had previous CVD were excluded, and 932 participants were lost to follow-up. Ultimately, 9935 participants were eligible for the analysis of the associations of the BRI trajectories with the incidence of CVD (Figure 1). The CHARLS was approved by the Institutional Review Board of Peking University. Written informed consent was obtained from all participants. This study was conducted following the

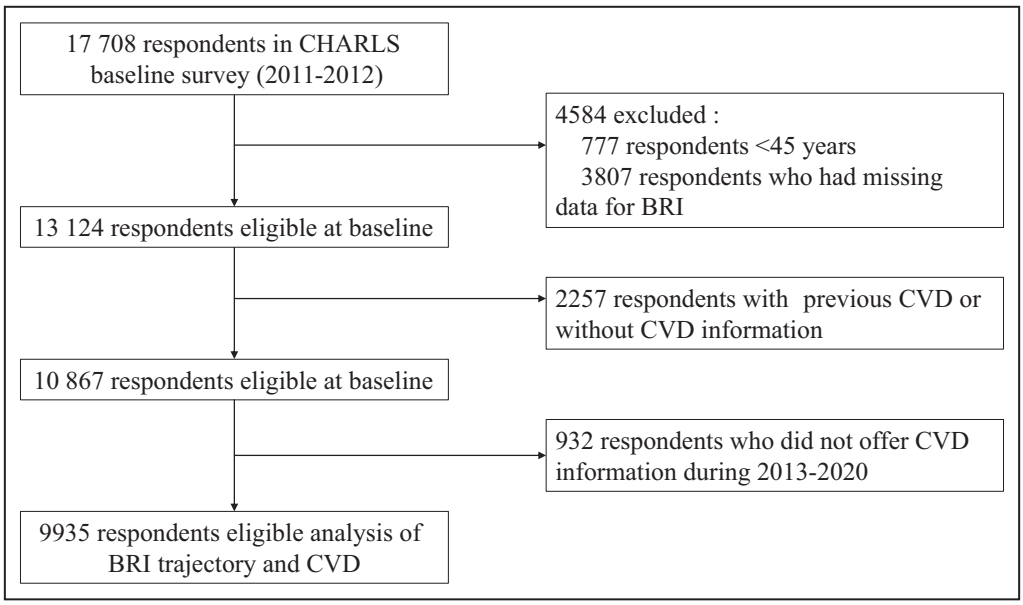


**Figure 1. Flowchart of participants' selection.**
BRI indicates the body roundness index; CHARLS, China Health and Retirement Longitudinal Study; and CVD, cardiovascular disease.

Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

## Data Collection

Blood samples were collected from each respondent by medically trained staff from the Chinese Center for Disease Control and Prevention on the basis of a standard protocol. The complete blood count was determined via automated analyzers available at county Center for Disease Control and Prevention stations or town/village health centers. Data on demographic characteristics and lifestyle risk factors were collected at baseline. A history of chronic disease was defined on the basis of a self-reported physician diagnosis. Blood pressure (BP) was measured with an electronic sphygmomanometer (HEM-7200 Monitor; Omron, Kyoto, Japan) after 5 minutes of rest in the sitting position. The mean of 3 BP measurements was used in the analyses. WC was measured by using nonstretched tape at the navel level at minimal respiration. Height was measured by a 213 stadiometer (Seca GmbH, Hamburg, Germany), with participants standing upright and barefoot on the floor board of the instrument. Anthropometric measurements were performed using standardized procedures.[14–16]

## Assessment of the BRI

The BRI was calculated as follows[7]:

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

. WC and height were measured to the nearest 0.1 cm.

## Study Outcomes

CVD events were assessed by the following questions: "Have you been told by a doctor that you had a heart attack, angina, coronary heart disease, heart failure, or other heart problems?" or "Have you been told by a doctor that you had a stroke?" Participants who reported heart disease or stroke were defined as having CVD. The primary outcome of the present study was incident CVD (stroke or cardiac events), which occurred in waves 4 and 5, and the secondary outcomes were included stroke and cardiac events, separately.[17,18]

## Statistical Analysis

The participants' baseline characteristics are presented as percentages for categorical variables, as the means with SDs for normally distributed variables and as medians with interquartile ranges for nonnormally distributed variables. Trajectories have been used to describe the dynamic course of studied factors as experienced over time.[19] The "PROC TRAJ" program in SAS 9.4 (SAS Institute, Cary, NC) was used to fit the model to group individuals with similar change patterns in the BRI from 2011 to 2016. We used group-based trajectory modeling to identify BRI trajectories. Although there was no gold standard for the best model selection, based on the opinions of Nagin,[20] who proposed group-based trajectory modeling and numerous influential studies, the choice of the best-fit model was evaluated by the following composite criteria: (1) observing improvement in the Bayesian

information criterion; (2) having at least 5% of participants in each trajectory class; (3) having mean posterior class membership probabilities >70%; (4) having odds of correct classification >5; and (5) confirming visually distinct trajectories. Initially, all BRI trajectories started with quadratic shapes and compared the Bayesian information criterion with the models of 2, 3, and 4 classes. The results showed that the optimal number of trajectories was 3 or 4. Given that there were only 2.28% participants in 1 of the subgroups, it was not considered conducive to model analyses of other trajectory groups if 4 classes were chosen and, therefore, a BRI trajectory model with 3 classes was selected. Next, different shape combinations for step-by-step membership in the 3 trajectory groups were tested for model fit. Finally, the best-fitting model was determined using distinct combinations, resulting in a model with the probabilities >0.7 (Tables S1–S4).[12,21] For convenience, we assigned labels to these tracks according to their modeled graphic patterns.

Demographic and clinical characteristics were compared between patients with different BRI trajectories by ANOVA or the Kruskal–Wallis test for continuous variables and the $\chi^2$ test for categorical variables. We computed hazard ratios (HRs) and 95% CIs for CVD incidence, stroke incidence, and cardiac events by assigned trajectories using Cox proportional hazards regression models. All these analyses were adjusted for the following covariates: demographic variables, including age, sex, place of residence, current smoking status, and current drinking status in model 1; medical history (hypertension, dyslipidemia, diabetes, chronic kidney disease, lung disease, liver disease); medication history (taking any medicine or treatment for hypertension, dyslipidemia, and diabetes) in model 2; and systolic BP and low-density lipoprotein cholesterol, blood glucose, uric acid, and high-sensitivity C-reactive protein levels in Model 3. Furthermore, we evaluated the ability of the BRI trajectory to reclassify risks on the basis of a conventional model with traditional risk factors. The net reclassification improvement (NRI) and integrated discrimination improvement (IDI) were calculated. The definition of the conventional model was established according to previous studies and included all traditional risk factors in the aforementioned multivariable adjusted model.[22]

Subgroup analyses were further assigned to evaluate the association between BRI trajectories and CVD risk according to sex, age (<65 and ≥65 years), place of residence, current smoking status, current drinking status, history of diabetes, antihypertension status, antidiabetes status, and baseline systolic BP (<140.0 and ≥140.0 mm Hg) in multivariable Cox proportional hazards regression models. In addition, we performed sensitivity analysis by excluding death as a competing risk event. The sample weights were not used in this study because previous studies have shown similar results with and without weighting.[23–25] A 2-sided *P* value <0.05 was considered to indicate statistical significance. The data analysis was performed using SAS statistical software version 9.4.

# RESULTS

## Baseline Characteristics

A total of 9935 participants (5263 men and 4672 women) were included in this study, and the baseline information is presented in Table 1. The average age was 58.85±9.09 years. The model with 3 BRI trajectories among the 9935 participants was determined to be the best-fitting model on the basis of the Bayesian information criterion, posterior probability of class members, and classification to assess the goodness-of-fit of the group-based trajectory modeling model. There were 3 trajectories: the low-stable, moderate-stable and high-stable trajectories (Figure 2). Compared with participants with the low-stable BRI trajectory, those with the high-stable BRI trajectory were more likely to be older and men; to live in rural areas; to have a lower rate of smoking and drinking; to have a greater incidence of hypertension, dyslipidemia, diabetes, and lung disease; to have a greater rate of taking antihypertensive drugs, lipid-lowering drugs, and antidiabetic drugs; and to have higher systolic BP, blood glucose, low-density lipoprotein cholesterol, uric acid, and high-sensitivity C-reactive protein levels (Table 1).

## Associations Between BRI Trajectories and CVD Incidence

From 2017 to 2020 (waves 4 and 5), we documented 3052 CVD events (including 965 stroke and 2477 cardiac events). Furthermore, 894 deaths were recorded. According to the crude model, compared with that in the low-stable group, in the moderate-stable and high-stable groups, the risk of incident CVD increased by 61% (HR, 1.61 [95% CI, 1.47–1.76]) and 163% (HR, 2.63 [95% CI, 2.25–3.07]), respectively. After we adjusted for demographic variables (age, sex, place of residence, current smoking status, and current drinking status), medical history (hypertension, dyslipidemia, diabetes, chronic kidney disease, lung disease, liver disease), and medication history (taking any medicine or treatment for hypertension, dyslipidemia, or diabetes) in models 1 and 2, significant results were still observed in the moderate-stable group and high-stable group. After further fully adjusting for clinical characteristic variables (systolic BP and blood glucose, low-density lipoprotein cholesterol, uric acid, and high-sensitivity C-reactive protein levels), the moderate-stable group and high-stable group also had a greater risk of CVD (HR, 1.22 [95% CI, 1.09–1.37]; HR, 1.55 [95% CI, 1.26–1.90],

**Table 1. Baseline Characteristics of the Study Participants According to the Trajectories of the BRI**

| Characteristics | BRI trajectories | | | *P* value |
|---|---|---|---|---|
| | Low-stable | Moderate-stable | High-stable | |
| Subjects | 4949 (49.81) | 4207 (42.35) | 779 (7.84) | |
| Demographics | | | | |
| Age, y | 58.70±8.93 | 58.59±9.10 | 61.18±9.73 | 0.002 |
| Male sex | 1907 (38.53) | 2700 (64.18) | 656 (84.21) | <0.0001 |
| Rural | 1386 (28.01) | 1577 (37.49) | 315 (40.44) | <0.0001 |
| Current smoking | 2093 (42.47) | 900 (21.44) | 92 (11.83) | <0.0001 |
| Current drinking | 2021 (40.84) | 1138 (27.05) | 124 (15.92) | <0.0001 |
| Medical history | | | | |
| Hypertension | 776 (15.78) | 1287 (30.74) | 380 (48.84) | <0.0001 |
| Dyslipidemia | 240 (4.95) | 501 (15.13) | 155 (20.56) | <0.0001 |
| Diabetes | 170 (3.47) | 303 (7.27) | 95 (12.27) | <0.0001 |
| Chronic kidney disease | 281 (5.71) | 219 (5.23) | 36 (4.65) | 0.36 |
| Lung disease | 491 (9.96) | 358 (8.53) | 93 (11.95) | 0.003 |
| Liver disease | 169 (3.44) | 138 (3.30) | 31 (4.02) | 0.59 |
| Medicine history | | | | |
| Antihypertensive drugs | 524 (10.65) | 951 (22.72) | 320 (41.13) | <0.0001 |
| Lipid-lowering drugs | 118 (2.43) | 271 (6.57) | 95 (12.63) | <0.0001 |
| Antidiabetic drugs | 106 (2.16) | 195 (4.68) | 59 (7.62) | <0.0001 |
| Clinical features | | | | |
| BRI | 3.18 (2.67–3.65) | 4.84 (4.31–5.43) | 6.90 (6.34–7.51) | <0.0001 |
| Systolic BP, mm Hg | 122.0 (110.5–135.5) | 128.0 (116.0–143.5) | 135.75 (122.5–150.5) | <0.0001 |
| Blood glucose, mg/dL | 100.62 (92.88–110.34) | 103.32 (95.58–114.66) | 105.57 (96.30–118.70) | <0.0001 |
| Low-density lipoproteins cholesterol, mg/dL | 110.57 (90.85–131.83) | 117.91 (95.88–141.11) | 121.78 (99.36–147.68) | <0.0001 |
| Uric acid, mg/dL | 4.26 (3.54–5.10) | 4.25 (3.57–5.13) | 4.36 (3.64–5.25) | 0.04 |
| High-sensitivity C-reactive protein, mg/L | 0.80 (0.45–1.69) | 1.11 (0.62–2.16) | 1.66 (0.93–3.34) | <0.0001 |

Continuous variables are expressed as mean±SD (normal distribution) or median (interquartile range; not normal distribution) and compared using *F* tests (normal distribution) or Wilcoxon rank-sum tests (not normal distribution) as appropriate. Categorical variables are expressed as n (%) and compared using $\chi^2$ tests. BP indicates blood pressure; and BRI, body roundness index.

respectively) than did the low-stable group. The risk of stroke and cardiac events was also significantly greater among participants with elevated BRI trajectories. The multivariable adjusted HR for stroke incidence in the moderate-stable group versus low-stable group was 1.29 (95% CI, 1.08–1.54) and that for cardiac events was 1.14 (95% CI, 1.01–1.29). The HR for the high-stable group versus low-stable group was 1.46 (95% CI, 1.10–1.95) for stroke and 1.35 (95% CI, 1.09–1.67) for cardiac events (Table 2).

Simultaneously adding the BRI trajectory to the model containing conventional risk factors significantly improved the risk reclassification for CVD (continuous NRI: 16.35%, *P*<0.0001; IDI: 0.32%, *P*<0.0001), stroke (continuous NRI: 14.79%, *P*<0.0001; IDI: 0.16%, *P*=0.0004) and cardiac events (continuous NRI: 15.64%, *P*<0.0001; IDI: 0.17%, *P*<0.0001). (Table 3).

## Subgroup Analysis

To further investigate the relationship between BRI trajectories and CVD incidence, a series of subgroup analyses were conducted. None of the subgroups, including the sex, age, current drinking status, current smoking status, history of diabetes, use of any medicine or treatment for hypertension and diabetes, and systolic BP subgroups, profoundly changed the relationship between the BRI trajectories and CVD incidence (all *P* for interaction >0.05) (Table 4).

## Sensitivity Analysis

A sensitivity analysis showed similar results to those of the primary analysis. After excluding participants who died in wave 4 or wave 5, the results were consistent with those of the primary analysis. The risk of CVD was 0.29 (HR, 1.29 [95% CI, 1.12–1.48]) and 0.66 (HR, 1.66 [95% CI, 1.32–2.08]) times greater among participants in the moderate-stable group and high-stable group, respectively, than among those in the low-stable group (Table 5).

# DISCUSSION

In our study, we investigated the BRI trajectories of a nationally representative sample of 9935 Chinese middle-aged and older adults. Furthermore, we explored the

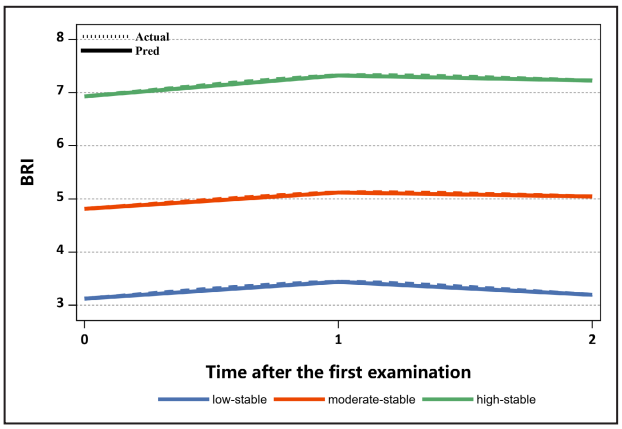


**Figure 2. Trajectories of body roundness index (BRI) among the CHARLS participants.**
CHARLS indicates China Health and Retirement Longitudinal Study.

development of different BRI trajectories before the diagnosis of CVD. Our group-based trajectory model revealed 3 different BRI trajectories, namely, the low-stable, moderate-stable, and high-stable BRI trajectories. The longitudinal BRI trajectories were significantly associated with CVD risk. The trajectories characterized by an increasing and persistent BRI were associated with a greater risk of developing CVD, stroke, or cardiac events, independent of age, sex, and other covariates. These findings indicated that experiencing a prolonged increase in the BRI would increase the risk of CVD. The inclusion of conventional risk factors in the BRI trajectories significantly improved the reclassification of CVD risk, as evidenced by the NRI and IDI. Furthermore, the association persisted after sensitivity and subgroup analyses.

Abdominal obesity refers to the proliferation and hypertrophy of adipocytes. This may lead to functional changes in adipocytes, such as the abnormal secretion of anti-inflammatory factors and proinflammatory factors,[26,27] the abnormal metabolism of free fatty acids,[28] and cell hypoxia,[29] affecting individuals' arterial stiffness[30] or cardiovascular function and increasing their risk of CVD.[28,29,31] WC measurement to assess abdominal obesity is often easier than imaging to assess visceral fat. However, the main drawback of WC measurement is that it does not take into account the effect of height, which may lead to the underestimation or overestimation of abdominal obesity in short or tall people.[32] Therefore, researchers have proposed a new body measurement index, namely, the BRI. This index is calculated by WC relative to height and has better performance than WC in predicting the percentage of body fat and visceral adipose tissue.[7]

Regarding the potential mechanisms related to BRI and CVD risks, there may be the following points: First, obesity is related to hypertension, dyslipidemia, and diabetes, all of which are risk factors for CVD, some of which may lead to CVD in turn.[33–35] Second, obesity may lead to increased production of proinflammatory

**Table 2. Risk of CVD by Trajectory of the BRI**

| Characteristics | BRI trajectory, HR (95%) | | | *P* trend |
|---|---|---|---|---|
| | Low-stable | Moderate-stable | High-stable | |
| Model 0 | | | | |
| CVD | 1.00 (Ref) | 1.61 (1.47–1.76) | 2.63 (2.25–3.07) | <0.001 |
| Stroke | 1.00 (Ref) | 1.46 (1.27–1.68) | 2.24 (1.80–2.78) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.59 (1.45–1.76) | 2.06 (2.14–2.94) | <0.001 |
| Model 1 | | | | |
| CVD | 1.00 (Ref) | 1.49 (1.36–1.64) | 2.23 (1.90–2.62) | <0.001 |
| Stroke | 1.00 (Ref) | 1.52 (1.31–1.76) | 2.29 (1.81–2.88) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.42 (1.28–1.57) | 2.00 (1.69–2.36) | <0.001 |
| Model 2 | | | | |
| CVD | 1.00 (Ref) | 1.23 (1.12–1.36) | 1.47 (1.23–1.76) | <0.001 |
| Stroke | 1.00 (Ref) | 1.24 (1.06–1.45) | 1.55 (1.21–1.99) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.18 (1.06–1.31) | 1.31 (1.09–1.58) | <0.001 |
| Model 3 | | | | |
| CVD | 1.00 (Ref) | 1.22 (1.09–1.37) | 1.55 (1.26–1.90) | <0.001 |
| Stroke | 1.00 (Ref) | 1.29 (1.08–1.54) | 1.46 (1.10–1.95) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.14 (1.01–1.29) | 1.35 (1.09–1.67) | <0.001 |

Model 0: crude model without any adjustments; Model 1: adjusted for age, sex, rural region, current smoking, and current drinking. Model 2: adjusted for model 1+medical history (hypertension, dyslipidemia, diabetes, chronic kidney disease, lung disease, liver disease)+medicine history (taking any medicine or treatment for hypertension, dyslipidemia, diabetes). Model 3: adjusted for model 2+systolic blood pressure, low-density lipoprotein cholesterol, blood glucose, uric acid, and high-sensitivity C-reactive protein. BRI indicates body roundness index; CVD, cardiovascular disease; and HR, hazard ratio.

**Table 3. Reclassification Statistics for Study Outcomes by Trajectory of the BRI**

| | Continuous NRI (95% CI), % | *P* value | IDI (95% CI), % | *P* value |
|---|---|---|---|---|
| CVD | | | | |
| Conventional model | Reference | | Reference | |
| Conventional model + trajectory of BRI | 16.35 (10.69–22.01) | <0.0001 | 0.32 (0.17–0.48) | <0.0001 |
| Stroke | | | | |
| Conventional model | Reference | | Reference | |
| Conventional model + trajectory of BRI | 14.79 (9.13–20.45) | <0.0001 | 0.16 (0.07–0.25) | 0.0004 |
| Cardiac events | | | | |
| Conventional model | Reference | | Reference | |
| Conventional model + trajectory of BRI | 15.64 (9.98–21.30) | <0.0001 | 0.17 (0.09–0.26) | <0.0001 |

Conventional model included age, sex, rural region, current smoking, current drinking, medical history (hypertension, dyslipidemia, diabetes, chronic kidney disease, lung disease, liver disease), medicine history (taking any medicine or treatment for hypertensive, dyslipidemia, diabetes), systolic blood pressure, low-density lipoprotein cholesterol, blood glucose, uric acid, and high-sensitivity C-reactive protein.

BRI indicates body roundness index; CVD, cardiovascular disease; IDI, integrated discrimination index; and NRI, net reclassification improvement.

cytokines, increased oxidative stress, excessive hemodynamic load, and activation of neurohormones, all of which may lead to left ventricular remodeling.[36–38] Third, obesity may cause structural and functional damage to the heart, as obesity directly damages the myocardium.[39]

**Table 4. Subgroup Analysis of BRI Trajectories for CVD**

| Characteristics | BRI trajectories | | | *P* trend | *P* interaction |
|---|---|---|---|---|---|
| | Low-stable | Moderate-stable | High-stable | | |
| Sex | | | | | |
| Male | 1.00 (Ref) | 1.33 (1.09–1.62) | 1.06 (0.63–1.80) | 0.02 | 0.14 |
| Female | 1.00 (Ref) | 1.23 (1.02–1.47) | 1.77 (1.37–2.28) | <0.001 | |
| Age, y | | | | | |
| <65 | 1.00 (Ref) | 1.30 (1.12–1.52) | 1.70 (1.31–2.20) | <0.001 | 0.13 |
| ≥65 | 1.00 (Ref) | 1.18 (0.90–1.53) | 1.50 (1.01–2.24) | <0.05 | |
| Current drinking | | | | | |
| Yes | 1.00 (Ref) | 1.35 (1.07–1.70) | 1.26 (0.75–2.10) | 0.03 | 0.08 |
| No | 1.00 (Ref) | 1.24 (1.05–1.46) | 1.70 (1.33–2.17) | <0.001 | |
| Current smoking | | | | | |
| Yes | 1.00 (Ref) | 1.35 (1.06–1.72) | 1.20 (0.67–2.16) | 0.04 | 0.12 |
| No | 1.00 (Ref) | 1.2 (1.06–1.46) | 1.66 (1.31–2.11) | <0.001 | |
| History of diabetes | | | | | |
| Yes | 1.00 (Ref) | 0.81 (0.49–1.56) | 0.84 (0.37–1.90) | 0.64 | 0.81 |
| No | 1.00 (Ref) | 1.29 (1.12–1.48) | 1.68 (1.34–2.11) | <0.001 | |
| Antihypertensive drugs | | | | | |
| Yes | 1.00 (Ref) | 1.42 (1.02–1.97) | 1.35 (0.87–2.07) | 0.14 | 0.06 |
| No | 1.00 (Ref) | 1.22 (1.05–1.41) | 1.78 (1.38–2.30) | <0.001 | |
| Antidiabetic drugs | | | | | |
| Yes | 1.00 (Ref) | 1.26 (0.57–2.75) | 1.54 (0.51–4.62) | 0.43 | 0.16 |
| No | 1.00 (Ref) | 1.28 (1.12–1.46) | 1.62 (1.30–2.02) | <0.001 | |
| Systolic BP | | | | | |
| <140.0 mm Hg | 1.00 (Ref) | 1.35 (1.15–1.58) | 1.73 (1.32–2.27) | <0.001 | 0.07 |
| ≥140.0 mm Hg | 1.00 (Ref) | 1.05 (0.82–1.36) | 1.41 (0.98–2.01) | 0.09 | |

In the multivariate models, confounding factors such age, sex, rural region, current smoking, current drinking, medical history (hypertension, dyslipidemia, diabetes, chronic kidney disease, lung disease, liver disease), medicine history (taking any medicine or treatment for hypertensive, dyslipidemia, diabetes), systolic blood pressure, low-density lipoprotein cholesterol, blood glucose, uric acid, and high-sensitivity C-reactive protein were included unless the variable was used as a subgroup variable. BP indicates blood pressure; BRI, body roundness index; and CVD, cardiovascular disease.

**Table 5. Sensitivity Analysis of BRI Trajectories for CVD**

| Characteristics | BRI trajectory, HR (95% CI) | | | *P* trend |
|---|---|---|---|---|
| | Low-stable | Moderate-stable | High-stable | |
| Model 0 | | | | |
| CVD | 1.00 (Ref) | 1.55 (1.40–1.73) | 2.38 (2.00–2.83) | <0.001 |
| Stroke | 1.00 (Ref) | 1.48 (1.26–1.74) | 2.53 (2.00–3.20) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.51 (1.34–1.70) | 2.12 (1.76–2.57) | <0.001 |
| Model 1 | | | | |
| CVD | 1.00 (Ref) | 1.51 (1.35–1.69) | 2.15 (1.79–2.57) | <0.001 |
| Stroke | 1.00 (Ref) | 1.60 (1.35–1.90) | 2.74 (2.13–3.53) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.38 (1.22–1.57) | 1.75 (1.44–2.14) | <0.001 |
| Model 2 | | | | |
| CVD | 1.00 (Ref) | 1.27 (1.13–1.43) | 1.56 (1.28–1.89) | <0.001 |
| Stroke | 1.00 (Ref) | 1.28 (1.07–1.54) | 1.87 (1.43–2.45) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.19 (1.04–1.35) | 1.33 (1.08–1.64) | <0.001 |
| Model 3 | | | | |
| CVD | 1.00 (Ref) | 1.29 (1.12–1.48) | 1.66 (1.32–2.08) | <0.001 |
| Stroke | 1.00 (Ref) | 1.34 (1.10–1.65) | 1.64 (1.19–2.25) | <0.001 |
| Cardiac events | 1.00 (Ref) | 1.17 (1.00–1.36) | 1.45 (1.13–1.85) | <0.001 |

Model 0: crude model without any adjustments. Model 1: adjusted for age, sex, rural region, current smoking, and current drinking. Model 2: adjusted for model 1+medical history (hypertension, dyslipidemia, diabetes, chronic kidney disease, lung disease, liver disease)+medicine history (taking any medicine or treatment for hypertensive, dyslipidemia, diabetes). Model 3: adjusted for model 2+systolic blood pressure, low-density lipoprotein cholesterol, blood glucose, uric acid, high-sensitivity C-reactive protein. BRI indicates body roundness index; CVD, cardiovascular disease; and HR, hazard ratio.

Previous studies have focused on the potential role of the BRI in CVD incidence or cardiometabolic risk factors.[9,40,41] A large Chinese cross-sectional study revealed that the BRI was better than other indicators for predicting CVD risk factors in a Chinese population.[40] Xu et al[9] also found that the BRI is a superior indicator associated with cardiometabolic risk. Furthermore, Maessen et al[42] showed that, compared with that in the lowest BRI quintile, the incidence of CVD in the other quintiles was significantly greater, and the area under the receiver operating characteristic curve also indicated that the BRI could accurately reveal cardiometabolic risk factors. Previous studies focusing on the relationship between the BRI and CVD mainly used single measurements in case–control or longitudinal cohort designs. However, the dynamic changes in the BRI vary across different populations. Therefore, a single measurement may not adequately or accurately reflect an individual's BRI status. Group-based trajectory modeling simultaneously takes into account the average variability and direction of variability to investigate the heterogeneity in BRI trajectories. Individuals who share similar BRI trajectories are assigned to groups, which is an effective approach for reflecting the life course of the BRI and its potential effect on CVD incidence. Recent studies have also focused on the relationship between trajectory models and CVD incidence. For instance, Wang et al[43] investigated the association between WC trajectories and CVD incidence. Blond et al[44] found that body mass index trajectories within the normal weight range and within the overweight range were associated with a worse CVD risk profile than the lowest body mass index trajectory. Studies of BRI trajectories conducted by Wu et al[12] and Ding et al[13] found that higher BRI values were associated with an increased risk of CVD over time. Our conclusions are consistent with these findings. In addition, we have adjusted for some confounders, such as taking any medicine or treatment for hypertension, dyslipidemia, and diabetes. The sex ratio in this study is balanced. These were not available in the previous study.

Our study possesses multiple advantages, such as the inclusion of a large, diverse sample of middle-aged and older individuals from across China, ensuring the reliability of our findings. Additionally, rather than relying on a single measurement of the BRI, we analyzed trajectories of change over time, providing a more comprehensive understanding of how the BRI fluctuates in this population. This approach adds further value to long-term monitoring of the BRI in middle-aged and older adults. There are some limitations to this study that require mentioning. First, the CHARLS data set is specific to the Chinese demographic, which raises questions about the generalizability of our findings to different cultural or ethnic groups. Second, the length of the study, particularly the 5-year span from 2011 to 2016 to assess changes in the BRI, and the

subsequent follow-up from 2017 to 2020, may be considered too brief. Nonetheless, this brief timeline could suggest that significant associations between BRI trajectories and the risk of CVD can be identified in a relatively short period. Third, consistent with other previous studies,[18,45] CVD diagnosis in this study relied on self-reported physician assessments, which may cause information bias. However, research[46] had shown that 77.5% of self-reported coronary heart disease cases are validated by medical records by the English Longitudinal Study of Aging researchers. Furthermore, the CHARLS database lacks specificity regarding the exact cause of death, leading us to focus solely on CVD as the outcome. Despite our efforts to control for variables, there remains a chance of unmeasured bias, such as the influence of physical activity. Additionally, the current analysis was not prespecified, and thus may be subject to biases from unaccounted factors. Consequently, future research is necessary to corroborate our findings.

In conclusion, long-term BRI patterns were associated with an altered risk of CVD; higher BRI trajectories were associated with an increased risk of CVD. The longitudinal trajectory of the BRI could be used as a novel indicator of CVD risk, providing a new possibility for CVD prevention.

## ARTICLE INFORMATION

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### Disclosures

None.

### Supplemental Material

Tables S1–S4

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