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Association of combined body mass index and central obesity with cardiovascular disease in middle-aged and older adults: a population-based prospective cohort study

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Abstract

Background Cardiovascular diseases (CVDs) pose a significant threat to public health. Evidence indicates that the combination of central obesity and normal body mass index (BMI) is associated with an increased risk of cardiovascular disease and mortality. However, limited evidences exists in middle aged and elderly adults in China.

Methods This was a prospective cohort study that utilized a nationally representative sample of 6,494 adults aged 45 years and above. These individuals participated in the China Health and Retirement Longitudinal Study spanning from 2011 to 2018. Height, weight and waist circumference (WC) were measured, and BMI was calculated by height and weight. Other variables were obtained through self-reported questionnaires. Association analysis was conducted using Cox proportional hazard regression models.

Results A total of 10,186 participants were investigated, with 57,185 person-years of follow-up. During this period, 1,571 CVDs occurred, including 1,173 heart diseases and 527 strokes. After adjusting for various factors including age, gender, education, marital status, smoking status, alcohol intake, social activity, hypertension, dyslipidemia, diabetes, cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, ENP(emotional, nervous, or psychiatric problems), memory related disease, arthritis or rheumatism, asthma, self-rated health and depression, the results revealed that compared to those with normal WC normal body mass index (BMI), individuals with central obesity normal BMI had a 27.9% higher risk of CVD incidence (95% confidence interval [CI]:1.074–1.524), and a 33.4% higher risk of heart disease incidence (95% CI:1.095–1.625), while no significant association was found with stroke. Additionally, those with normal WC high BMI showed a 24.6% higher risk of CVD incidence (95% CI:1.046–1.483), and a 29.1% higher risk of heart disease incidence (95% CI:1.045–1.594), again with no significant association with stroke. Finally, individuals with central obesity high BMI exhibited a 49.3% higher risk of CVD incidence (95% CI:1.273–1.751), a 61% higher risk of heart disease incidence (95% CI:1.342–1.931), and a 34.2% higher risk of stroke incidence (95% CI:1.008–1.786). Age- and sex- specific analyses further revealed varying trends in these associations.

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Conclusions We discovered that the combined association of body mass index(BMI) and central obesity with CVD incidence exhibited a significantly enhanced predictive value. Specifically, a high BMI with central obesity was notably linked to an increased risk of CVD incidence. Additionally, central obesity with a normal BMI or a normal WC coupled with a high BMI significantly augmented the risk of heart disease incidence, but not stroke. Notably, male and middle-aged adults demonstrated a greater propensity for heart disease incidence. Our study underscores the importance of maintaining an optimal BMI and preventing abdominal obesity in promoting cardiovascular health.

Keywords Central obesity, BMI, Cardiovascular disease, Heart disease, Stroke

Introduction

Cardiovascular disease (CVD) is an important global health concern, with an estimated 17.9 million mortality in 2016, representing 31% of all global fatalities [1]. Despite a decline in CVD mortality over the past decades [2], it remains a leading cause of death and a significant obstacle to sustainable human development. The situation is particularly grave in low- and middle-income countries, accounting for over three-quarters of CVD deaths, according to the WHO [3]. As the aging process accelerates in China, the prevalence and mortality of CVD continue to soar, imposing a significant economic burden [4]. Consequently, the prevention of CVD is paramount for public health.

To enhance cardiovascular health, the American Heart Association established its 2020 Strategic Impact Goal and introduced a simplified assessment tool grounded in four health behaviors, including body mass index (BMI) as one of them [5]. BMI is a commonly used metric to gauge general obesity [6]. In both developed and developing countries, the global prevalence of general obesity and overweight has witnessed a remarkable surge in the past decades. In 2010, approximately 1.6 billion individuals worldwide were overweight, and 400 million were obese [7]. The proportion of overweight and obese individuals in China is high, account for 66.93% in a particular study [8]. Among middle-aged and older adults in China, the prevalence of obesity is 11.53% [9]. BMI serves as a common representation of an individual's body fat index, and its increase is widely recognized as a risk factor for CVDs [6]. While investigations into BMI in the prognosis of acute coronary syndrome have yielded interesting results [10], recent evidence suggests that BMI is not an optimal indicator of body fat percentage, and its effectiveness as a risk factor of CVDs had been questioned. BMI fails to distinguish between lean and fat masses and does not indicate body fat distribution [11]. Central obesity, on the other hand, is a widely acknowledged indicator of measuring central adiposity, as opposed to BMI. The prevalence of central obesity and its association with CVD risks and incidence have increased markedly over the last few decades [12–14].

Although some studies have explored the relationship between cardiovascular health and the combination of BMI and central obesity, the majority of them have concentrated on the central obesity normal BMI and yielded a significant findings [15–18]. However, a long prospective study in China has yet to uncover the association between cardiovascular incidence and the combined effect of BMI and central obesity.

This study aimed to examine the association of BMI and central obesity combination with cardiovascular incidence in a 7-year prospective nationally representative sample in China.

Methods

Study population

The China Health and Retirement Longitudinal Study (CHARLS), conducted by the National School for Development (China Center for Economic Research), is a large-scale, multistage, ongoing, nationally representative health survey of civilians in China [19]. Samples of households with members aged 45 years and above were chosen, and 17,708 individuals in 10,257 households, 450 villages nationwide, and 150 counties and districts from 28 provinces were selected in the baseline year, 2011, with a response rate of 80.51%. Detailed descriptions of the CHARLS 2011 procedures and sampling methods have been extensively described [20]. The medical ethics committee approved the CHARLS study, and all participants gave informed consent. Ethical approval for data collection in CHARLS was obtained from the Biomedical Ethics Review Committee of Peking University (IRB00001052–11015).

Information of exposure and covariant variables was acquired from CHARLS 2011 survey. The data for this study were sourced from the CHARLS for the years 2011 and 2018. The standardized questionnaire employed in this study is the one developed by the CHARLS project, accessible via CHARLS's official website (http://charls.pku.edu.cn/) or cited in relevant scholarly articles [19, 21]. We included participants aged 45 years and above, who had no history of CVD at baseline, and possessed follow-up information on the incidence of heart disease and stroke. Those with missing information on age, gender, height, BMI, and waist circumference (WC) were excluded. After further screening to eliminate individuals with a BMI below 18.5 kg/m^2, 10,417 participants were ultimately selected for analysis (Fig. 1).

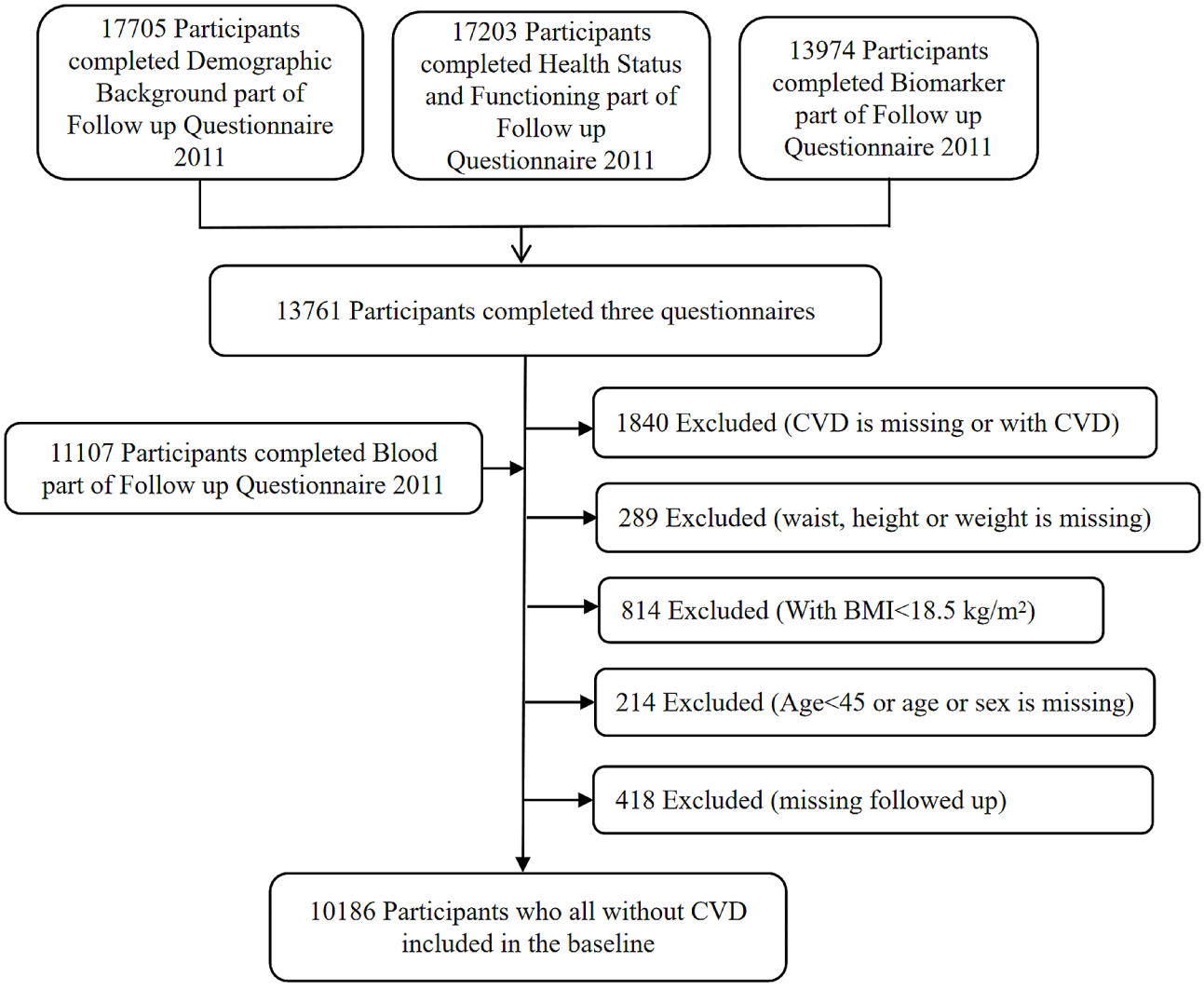

Fig. 1 Flow chart of participant selection

Outcome ascertainment

CVDs include heart diseases and stroke, which were self-reported in response to the questions, "Have you ever been diagnosed with heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems?" or "Have you ever been diagnosed with stroke?" by a doctor. "How did you know that you had heart disease through routine or CHARLS physical examination or any other?" or "How did you know that you had stroke through routine or CHARLS physical examination or any other?"Participants were followed from their enrollment date until the onset of heart disease, stroke, or the conclusion of the 2018 survey [22].

Exposure measurement

Exposure variables were categorized based on BMI and waist circumference. Specifically, all participants were divided into four groups: Normal waist circumference normal BMI (Normal WC normal BMI), central obesity normal BMI, normal waist circumference high BMI (Normal WC high BMI), and central obesity high BMI groups, according to BMI and waist circumference. BMI was defined as the weight (kg) divided by the height^2 (m^2). Height and weight were measured without shoes and using a stadiometer (SecaTM213 Stadiometer) and scale (OmronTMHN-286 Scale), respectively. BMI was categorized into normal BMI (BMI between 18.5 kg/m^2 and 24.9 kg/m^2) and high BMI (overweight with BMI between 25.0 and 29.9 kg/m^2 and obesity with BMI ≥ 30.0 kg/m^2) based on WHO criteria [23]. Participants with a BMI < 18.5 kg/m^2 were not included in the analysis. Waist circumference was classified into two groups: normal waist circumference and central obesity. Central obesity was defined as a waist circumference ≥ 80 cm for females and ≥ 102 cm for males [24].

Covariant assessment

We also included several relevant covariates to avoid potential bias based on previous CVD studies. Information on age, gender, educational level, marital status, smoking status, alcohol intake, social activity, hypertension, dyslipidemia, diabetes, cognitive function, and depression was collected using standardized questionnaires during interviews. Age was classified into middle-aged (45–64 years) and elderly (≥65 years) groups. Education level was categorized as illiterate, primary school and below, junior middle school, high school, or junior college and above. Marital status was classified as married, or others (i.e., separated, divorced or widowed). Smoking status was categorized as nonsmoker, past smoker, or current smoker based on their responses to questions about ever smoked, in the last interview, and at present. Alcohol intake was categorized as none, drinking much (more than once a month), or drinking little (less than once a month) according to alcohol consumption in the previous year. Social activity was categorized as active healthy activity when participants engaged in healthy activities (i.e., interacted with friends, went to a sport, social, or other kinds of clubs, took part in a community-related organization, done voluntary or charity work, and attended an educational or training course) and actively (frequency of activity was almost daily or almost every week), inactive healthy activity group when participants performed healthy activities but inactively (frequency of activity was not regular), inactive unhealthy activity group when participants engaged in unhealthy activities (i.e., played Ma-jong, played chess, played cards, stock investment, surf the Internet, and no such social activities), and inactively, active unhealthy activity group when participants actively engaged in unhealthy activities. Cardiometabolic disease, which includes hypertension, diabetes and dyslipidaemia.

Hypertension is diagnosed by questions of whether diagnosed by doctors before in the CHARLS questionnaire or blood test data with systolic/diastolic blood pressure≥140/90 mm Hg. Diabetes is diagnosed by questions of whether diagnosed by doctors before in the CHARLS questionnaire or fasting blood glucose>7.0 mmol/L in the blood test data. Dyslipidaemia was collected by questions of whether diagnosed by doctors before in the CHARLS questionnaire or one of the following criteria was reached in the blood test data, such as total cholesterol≥6.2 mmol/L, low-density lipoprotein cholesterol≥4.1 mmol/L, high-density lipoprotein cholesterol<1.0 mmol/L or triglycerides (TG)≥2.3 mmol/L [25]. Chronic diseases like cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, Emotional, Nervous, or Psychiatric Problems(ENP), memory related disease, arthritis or rheumatism, and asthma were investigated by CHARLS questionnaire as heart disease or stroke [26].

Depression was detected about the feeling and behave during the last week using the Center for Epidemiological Studies Depression Scale-10 (CESD-10), which is useful in the examination of different aspects of depression [25]. It consists of 10 items, response ranged from 0 to 3 for each item and the sum scores ranged from 0 to 30, with higher scores indicating higher degrees of depressive symptoms. Depression was classified into depressed group (CESD score≥10) and non-depressed group(CESD score<10) [27].

Statistics analysis

Means (SD) or medians (quartile ranges) were expressed as continuous variables, and counts (percentiles) for categorical variables. The chi-square and Mann-Whitney U tests were used to examine differences in categorical and continuous variables with heteroscedasticity, respectively. The incidence density and rate ratio were computed in units of 100,000 person-years. Kaplan–Meier estimates for the cumulative risk of CVD events were computed for the different BMI and waist categories and compared using the log-rank test. The associations between BMI, waist circumference, and cardiovascular incidence were investigated using Cox proportional hazards regression models with the following covariates: age, gender, education, and marital status (model 1); model 1 plus smoking status, alcohol intake, and social activity (model 2); model 2 plus hypertension, dyslipidemia, and diabetes (model 3). We further adjusted for chronic diseases (like cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, ENP, memory related disease, arthritis or rheumatism, asthma), self-rated health and depression (yes/no) using a separate model (Model 4) (see Table 1; Fig. 2 for central illustration). Bootstrap method of 5000 times resampling was used to estimate hazard ratios(HRs), and 95% confidence intervals of differences of each two HRs were calculated. We have checked model assumptions for all the analyses. Since there are few missing data in covariates, participants with missing data were omitted from the analysis. All statistical analyses were conducted using IBM SPSS software package version 20 (Armonk, NY, IBM Corp.). Two-sided $p<0.05$ were considered statistically significant.

Results

10,186 participants eligible were included in this study. The participants' age range was 45–96 years (mean age 58.58, standard deviation[SD] 9.284); 48.66% were males, and 24.48% were elderly. In this study, 49.62%($n=5054$), 19.14%($n=1950$), 10.78%($n=1098$), and 20.46%($n=2084$) had normal WC normal BMI, central obesity normal

Table 1 Associations of obesity and central obesity with CVD incidence

	Normal WC normal BMI	Central obesity normal BMI	Normal WC high BMI	Central obesity high BMI
CVD				
Incidence/person-yrs	636/28,219	328/10,971	180/6083	427/11,912
Unadjusted	1(ref)	1.312(1.149–1.499)	1.323(1.122–1.562)	1.553(1.374–1.756)
Model 1	1(ref)	1.4(1.179–1.662)	1.348(1.138–1.598)	1.726(1.481–2.011)
Model 2	1(ref)	1.401(1.179–1.664)	1.339(1.128–1.589)	1.725(1.479–2.012)
Model 3	1(ref)	1.274(1.071–1.514)	1.199(1.008–1.425)	1.483(1.267–1.736)
Model 4	1(ref)	1.281(1.075–1.525)	1.244(1.045–1.481)	1.49(1.271–1.748)
Model 5	1(ref)	1.279(1.074–1.524)	1.246(1.046–1.483)	1.493(1.273–1.751)
Heart disease				
Incidence/person-yrs	442/28,219	262/10,971	122/6083	347/11,912
Unadjusted	1(ref)	1.509(1.295–1.758)	1.29(1.056–1.577)	1.817(1.579–2.091)
Model 1	1(ref)	1.417(1.167–1.721)	1.35(1.098–1.659)	1.8(1.512–2.143)
Model 2	1(ref)	1.418(1.167–1.722)	1.345(1.093–1.656)	1.795(1.507–2.139)
Model 3	1(ref)	1.316(1.082–1.601)	1.233(0.999–1.521)	1.593(1.332–1.906)
Model 4	1(ref)	1.335(1.096–1.627)	1.288(1.043–1.591)	1.606(1.339–1.926)
Model 5	1(ref)	1.334(1.095–1.625)	1.291(1.045–1.594)	1.61(1.342–1.931)
Stroke				
Incidence/person-yrs	242/28,219	92/10,971	73/6083	120/11,912
Unadjusted	1(ref)	0.966(0.76–1.228)	1.411(1.086–1.834)	1.145(0.92–1.425)
Model 1	1(ref)	1.416(1.029–1.947)	1.368(1.046–1.79)	1.692(1.284–2.229)
Model 2	1(ref)	1.42(1.032–1.955)	1.357(1.035–1.779)	1.712(1.298–2.26)
Model 3	1(ref)	1.207(0.876–1.663)	1.13(0.858–1.487)	1.326(1-1.759)
Model 4	1(ref)	1.201(0.868–1.662)	1.162(0.881–1.534)	1.34(1.007–1.784)
Model 5	1(ref)	1.201(0.868–1.662)	1.162(0.881–1.534)	1.342(1.008–1.786)

Values are n or hazard ratios (95% confidence intervals). Model 1: adjusted for age, gender, education, and marital status. Model 2: Model 1 + Smoking status, alcohol intake, and social activity. Model 3: Model 2 + hypertension, dyslipidemia, and diabetes. Model 4: Model 3 + Cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, ENP, memory related disease, arthritis or rheumatism, asthma and self-rated health. Model 5: Model 4 + Depression. CVD, cardiovascular disease

BMI, normal WC high BMI, and central obesity high BMI, respectively.

During 57,185 person-years of follow-up (mean follow-up was 7 years, median follow-up was 5.6 years, maximum follow-up was 7 years), 1571 CVDs occurred, of which 1173 were heart disease and 527 were stroke. 7 years incidence density (ID) of CVD was 4005 (incidence relative risk [RR]: 1) for Normal WC normal BMI group, 2037 (RR:1.312) for Central obesity normal BMI group, 1101 (RR: 1.323) for Normal WC high BMI group, and 2637 (RR: 1.553) for Central obesity high BMI group; 7 years incidence density (ID) of heart disease was 2750 (RR: 1) for Normal WC normal BMI group, 1635 (RR:1.509) for Central obesity normal BMI group, 746 (RR:1.29) for Normal WC high BMI group, and 2153 (RR:1.817) for Central obesity high BMI group; 7 years ID of stroke was 1574 (RR:1) for Normal WC normal BMI group, 569 (RR:0.966) for Central obesity normal BMI group, 451 (RR:1.411) for Normal WC high BMI group, and 752 (RR:1.145) for Central obesity high BMI group.

The baseline descriptive analysis and comparisons were presented in Table 2. Participants exhibiting central obesity and a high BMI were more likely to be under 65 years old, female, with a illiteracy level of primary school or below, married, non-smokers, never consumed alcohol, social active, and without chronic diseases such as hypertension, dyslipidemia, diabetes, depression, cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, ENP, memory related disease, arthritis or rheumatism, asthma. They also tended to rate their health as fair.

The associations between obesity and central obesity with CVD, heart disease and stroke was presented in Table 1 (Fig. 2. for central illustration). After adjusted for age, gender, education, marital status, smoking status, alcohol intake, social activity, hypertension, dyslipidemia, diabetes, depression, nine chronic diseases and self-rated health, participants with central obesity normal BMI had a 27.9% higher risk (hazard ratio [HR]: 1.279; 95% confidence interval [CI]: 1.074–1.524) of CVD, while those with normal WC high BMI had a 24.6% higher risk (HR: 1.246; 95%CI: 1.046–1.483), and the risk for central obesity high BMI was 49.3% higher (HR: 1.493; 95%CI: 1.273–1.751) compared to the normal WC normal BMI group. For heart disease, central obesity normal BMI led to a 33.4% higher risk (HR: 1.334; 95%CI: 1.095–1.625), while normal WC high BMI increased the risk by 29.1% (HR: 1.291; 95%CI: 1.045–1.594) and central obesity high

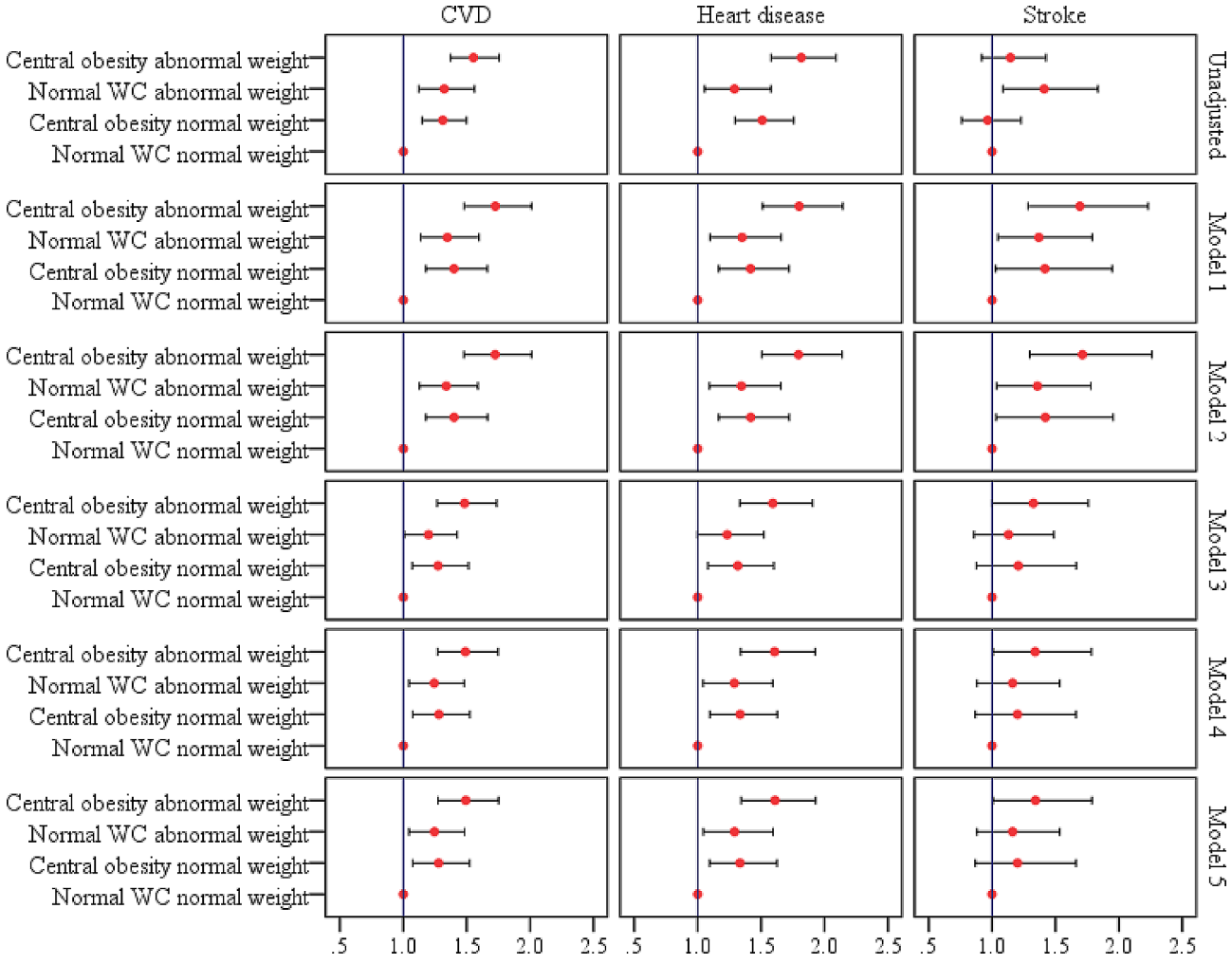

Fig. 2 Central illustration. Model 1: adjusted for age, gender, education, and marital status. Model 2: Model 1 + Smoking status, alcohol intake, and social activity. Model 3: Model 2 + hypertension, dyslipidemia, and diabetes. Model 4: Model 3 + Cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, ENP, memory related disease, arthritis or rheumatism, asthma and self-rated health. Model 5: Model 4 + Depression. CVD, cardiovascular disease

BMI posed a 61% higher risk (HR: 1.61; 95%CI: 1.342–1.931) compared to the normal WC normal BMI group. For stroke, participants with central obesity normal BMI did not show a higher risk (HR: 1.201; 95%CI: 0.868–1.662), nor did those with normal WC high BMI(HR: 1.162; 95%CI: 0.881–1.534). However, participants with central obesity and high BMI had a 34.2% higher risk (HR: 1.342; 95%CI: 1.008–1.786) compared to the normal WC normal BMI group.

We further examined the associations between BMI and waist circumference with CVD incidence, stratified by gender and age(Fig. 3). For male and female, the risks of CVD incidence and heart disease incidence were significantly higher among participants with central obesity high BMI compared to those with normal WC normal BMI. However, we did not observe a significantly higher risk of stroke incidence. Among middle-aged adults, there was a significant increase in the risks of CVD and heart disease incidence for those with central obesity high BMI, exhibiting a clear trend in odds ratios. Nevertheless, a significantly higher risk of stroke incidence in middle-aged adults and CVD and heart disease incidence in elders over 60 years was not found. For elders over 60 years, the risk of stroke incidences were significantly higher among participants with central obesity high BMI, as well as those with central obesity normal BMI, compared to those with normal WC normal BMI.

Discussion

In this large, nationally representative, prospective cohort study with a seven-year follow-up, we conducted an analysis to examine the association between combined BMI and waist circumference with the incidence of CVD, heart disease, stroke, and gender- and age-specific risks. Our findings indicated that compared to individuals with normal WC normal BMI, those with normal WC

Table 2 Baseline demographic and lifestyle characteristics of the Study Population

		Normal WC normal BMI	Central obesity normal BMI	Normal WC high BMI	Central obesity high BMI	*p*-value
Age (%)						< 0.001
45–64	7693	3728(73.8)	1368(70.2)	902(82.1)	1695(81.3)	
≥65	2493	1326(26.2)	582(29.8)	196(17.9)	389(18.7)	
Gender(%)						< 0.001
Male	4957	3681(72.8)	11(0.6)	1025(93.4)	240(11.5)	
Female	5229	1373(27.2)	1939(99.4)	73(6.6)	1844(88.5)	
Education level(%)						< 0.001
Illiteracy	2823	1140(22.6)	851(43.7)	106(9.7)	726(34.8)	
Primary school and below	4140	2252(44.6)	714(36.6)	422(38.5)	752(36.1)	
Junior middle school	2131	1097(21.7)	268(13.8)	354(32.3)	412(19.8)	
High school and above	1089	564(11.2)	116(6)	215(19.6)	194(9.3)	
Marital Status (%)						< 0.001
Married	8983	4472(88.5)	1602(82.2)	1041(94.8)	1868(89.6)	
Others	1203	582(11.5)	348(17.8)	57(5.2)	216(10.4)	
Smoking status (%)						< 0.001
Nonsmoker	6089	2114(41.8)	1789(91.7)	380(34.6)	1806(86.7)	
Past smoker	838	516(10.2)	38(1.9)	208(19)	76(3.6)	
Current smoker	3256	2422(47.9)	123(6.3)	509(46.4)	202(9.7)	
Alcoholic intake (%)						< 0.001
None	6667	2747(54.4)	1688(86.6)	490(44.7)	1742(83.6)	
Drinking little	838	496(9.8)	96(4.9)	120(10.9)	126(6)	
Drinking much	2679	1810(35.8)	166(8.5)	487(44.4)	216(10.4)	
Social activity (%)						< 0.001
No	5013	2581(51.1)	1030(52.8)	487(44.4)	915(43.9)	
Yes	5173	2473(48.9)	920(47.2)	611(55.6)	1169(56.1)	
Hypertension (%)						< 0.001
No	7307	3965(78.5)	1380(70.8)	679(61.8)	1283(61.6)	
Yes	2879	1089(21.5)	570(29.2)	419(38.2)	801(38.4)	
Dyslipidemia (%)						< 0.001
No	7197	3963(78.4)	1339(68.7)	661(60.2)	1234(59.2)	
Yes	2989	1091(21.6)	611(31.3)	437(39.8)	850(40.8)	
Diabetes (%)						< 0.001
No	9017	4600(91)	1719(88.2)	942(85.8)	1756(84.3)	
Yes	1169	454(9)	231(11.8)	156(14.2)	328(15.7)	
Depression (%)						< 0.001
No	5835	2981(59)	972(49.8)	742(67.6)	1140(54.7)	
Yes	4351	2073(41)	978(50.2)	356(32.4)	944(45.3)	
Cancer						0.002
No	10,052	4996(99.3)	1925(99.2)	1087(99.5)	2044(98.5)	
Yes	87	33(0.7)	16(0.8)	6(0.5)	32(1.5)	
Chronic Lung Diseases						< 0.001
No	9272	4542(90.2)	1796(92.6)	1003(91.6)	1931(92.9)	
Yes	874	492(9.8)	143(7.4)	92(8.4)	147(7.1)	
Liver Disease						0.368
No	9738	4825(96.3)	1877(97)	1048(95.8)	1988(96.2)	
Yes	369	185(3.7)	59(3)	46(4.2)	79(3.8)	
Kidney Disease						0.052
No	9574	4721(94.1)	1833(94.6)	1033(94.6)	1987(95.8)	
Yes	546	295(5.9)	104(5.4)	59(5.4)	88(4.2)	
Digestive Disease						< 0.001
No	7965	3893(77.4)	1493(76.8)	895(81.7)	1684(81)	
Yes	2184	1137(22.6)	450(23.2)	201(18.3)	396(19)	

Table 2 (continued)

		Normal WC normal BMI	Central obesity normal BMI	Normal WC high BMI	Central obesity high BMI	*p*-value
ENP						0.267
No	10,020	4969(98.8)	1914(98.7)	1090(99.5)	2047(98.8)	
Yes	115	59(1.2)	25(1.3)	6(0.5)	25(1.2)	
Memory Related Disease						0.920
No	10,067	4991(99.1)	1928(99.1)	1087(99.3)	2061(99.3)	
Yes	83	43(0.9)	17(0.9)	8(0.7)	15(0.7)	
Arthritis or Rheumatism						< 0.001
No	6821	3485(69.1)	1256(64.6)	757(69)	1323(63.5)	
Yes	3341	1555(30.9)	687(35.4)	340(31)	759(36.5)	
Asthma						0.309
No	9830	4864(96.8)	1889(97.2)	1056(96.5)	2021(97.5)	
Yes	305	161(3.2)	54(2.8)	38(3.5)	52(2.5)	
Self-rated health						< 0.001
very good	803	407(8.1)	127(6.5)	120(10.9)	149(7.2)	
good	1955	974(19.3)	328(16.8)	268(24.5)	385(18.5)	
fair	5417	2730(54)	1023(52.5)	555(50.6)	1109(53.2)	
poor	2005	940(18.6)	472(24.2)	153(14)	440(21.1)	

Values are *n* (%) for categorical variables

high BMI, central obesity normal BMI and central obesity high BMI were associated with a higher risk of CVD and heart disease incidence. Specifically, central obesity high BMI was also associated with a higher risk of stroke incidence. These results reaffirmed the cardiovascular benefits of maintaining a healthy weight and reducing abdominal fat.

Although previous studies have demonstrated an association between central obesity normal BMI and a higher risk of CVD incidence and CVD risk factors [28], our study also found a significant association between central obesity normal BMI and an increased risk of CVD incidence and heart disease incidence. However, we did not find a significant association between central obesity normal BMI and stroke incidence. Central obesity normal BMI refers to a condition where individuals have a normal body BMI but exhibit high central or visceral fat, which is strongly associated with cardiometabolic risk [29]. The prevalence of this "normal-weight metabolically obese" phenotype, determined through direct measurements of fat distribution or metabolic characteristics, ranges from 13% to 38% [30]. In our study, participants with central obesity normal BMI accounted for 19.14% of the cohort. A study estimated that in the US population, there were about 30 million Americans affected by normal weight obesity syndrome [31]. Both these studies and our study suggested that central obesity normal BMI should be paid attention to, especially for heart disease prevention in middle-aged adults and female.

In our study, we not only found a significant association between central obesity normal BMI and a higher risk of CVD incidence, but we also observed notable relationships between high BMI and an elevated risk of CVD. Specifically, both normal WC high BMI and central obesity high BMI were associated with a greater risk of CVD incidence and heart disease. Furthermore, central obesity high BMI displayed a higher risk of stroke incidence. While much research has focused on the connection between central obesity normal BMI with cardiovascular risk due to its potential for oversight, it is important to recognize that the relative risk posed by central obesity high BMI appears to be stronger. For instance, a study conducted in Korea revealed that individuals who exhibited both central obesity and obesity (BMI$\geq$25.0 kg/m^2) displayed the strongest correlation with all cardiovascular risk factors compared to those who did not exhibit either central obesity or obesity [32].

There is consensus that anthropometric measure of abdominal or central obesity serve as better predictors of cardiometabolic risk, and combining these two indices may further enhance predictive accuracy [33]. In our study, we observed similar results for the risk of CVD incidence and heart disease, but not for stroke [34]. These findings underscore the need for a comprehensive approach to cardiovascular risk assessment, one that considers not only BMI but also waist circumference and body fat distribution. As we progress in devising prevention and treatment strategies for CVD, it is crucial to acknowledge the pivotal role of central obesity and BMI, thereby emphasizing the imperative for prompt and timely interventions [35–38].

While we have accounted for 21 covariates, there are still some variables that potentially influence CVD incidence that have not been included, such as physical activity, or aerobic / muscular fitness [39, 40].

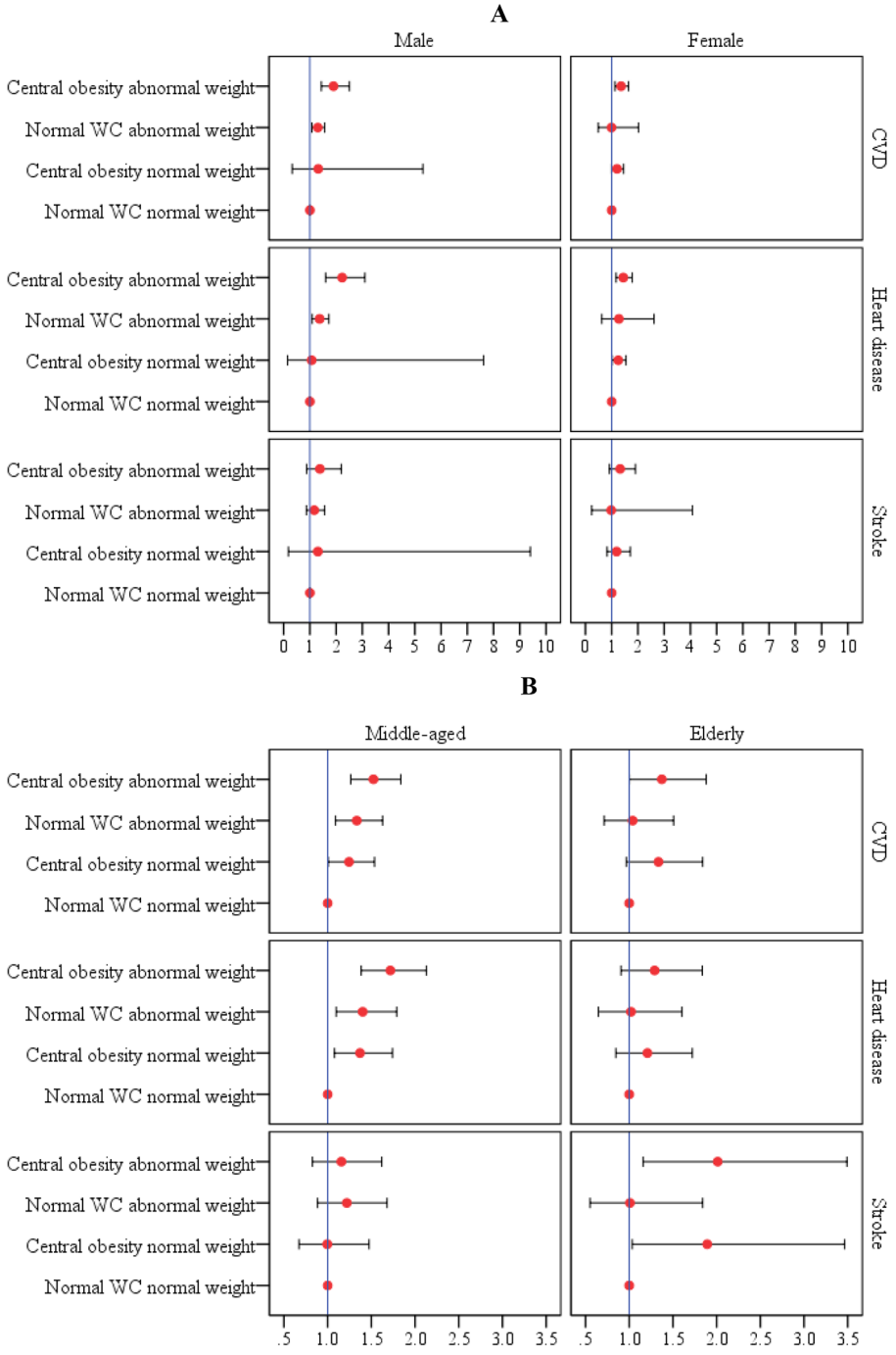

Fig. 3 Hazard ratios for CVD (include heart disease and stroke) incidence for participants of age < 65 years old, age ≥ 65 years old, men and women. Hazard ratios were adjusted for age, gender, education, marital status, smoking status, alcohol intake, social activity, hypertension, dyslipidemia, diabetes, cancer, chronic lung diseases, liver disease, kidney disease, digestive disease, ENP, memory related disease, arthritis or rheumatism, asthma, self-rated health and depression

Conclusions

In this extensive prospective study encompassing Chinese adults aged 45 years and above, we observed a notably elevated predictive value when considering the combined association of BMI and central obesity with CVD incidence. Specifically, the coexistence of central obesity and high BMI exhibited a significant correlation with CVD incidence, encompassing both heart disease and stroke, exhibiting a stronger association than either central obesity with normal BMI or normal waist

circumference with high BMI. Central obesity normal BMI and normal WC high BMI could only significantly increase the risk of heart disease incidence, but not stroke. Males and middle-aged adults exhibited a greater likelihood of developing heart disease. Our study underscores the benefits of maintaining a healthy BMI and preventing abdominal obesity in promoting cardiovascular health.

Abbreviations

BMI	Body Mass Index
CVD	Cardiovascular Disease
ENP	Emotional, Nervous, or Psychiatric problems
WC	Waist Circumstance

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Author contributions
LGH and XYL conceived of the presented idea. XYL conducted the data analyses. LGH, XYL and YXH wrote and reviewed the main manuscript. All of the authors approved the final version.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The data were from the China Health and Retirement Longitudinal Study, which was approved by the Ethical Review Committee of Beijing University (IRB00001050-11015) and signed informed consent was obtained from all participants. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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