Waist-to-Height Ratio, Waist Circumference, Body Mass Index and Risk of Cardiometabolic Multimorbidity: A National Longitudinal Cohort Study

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Abstract

Background: Cardiometabolic multimorbidity is an increasing public health burden. This study aimed to evaluate the association of waist-to-height ratio (WHtR), waist circumference (WC) and body mass index (BMI) with risk of cardiometabolic multimorbidity.

Methods: We used data from the China Health and Retirement Longitudinal Study (CHARLS). 10521 participants aged 45 and over were recruited, including 8807 individuals with 0 cardiometabolic disease at baseline (stage 0) and 1714 individuals with 1 cardiometabolic disease at baseline (stage 1). Logistic regression was conducted to estimate the odds ratios (ORs) and confidence intervals (CIs). Net reclassification index (NRI) and integrated discrimination improvement (IDI) were used to evaluate the incremental predictive value beyond conventional factors.

Results: In stage 0, increased risk of cardiometabolic multimorbidity was observed among participants with $WHtR \geq 0.5$ (OR: 1.76, 95% CI: 1.05–2.97), $WC \geq 85$ (men) + $WC \geq 75$ (women) (OR: 1.77, 95% CI: 1.05–2.97) or $BMI \geq 24$ (OR: 1.48, 95% CI: 0.98–2.24). Furthermore, both NRI and IDI of WHtR and WC were higher than those of BMI. In stage 1, the adjusted ORs (95% CIs) of $WHtR \geq 0.5$, $WC \geq 85$ (men) + $WC \geq 75$ (women), and $BMI \geq 24$ were 2.04 (1.24–3.35), 2.07 (1.28–3.34), and 1.47 (1.06–2.04), respectively. In addition, WC exhibited the highest NRI and IDI.

Conclusions: WHtR, WC and BMI are independent predictors of cardiometabolic multimorbidity in middle-aged and elderly Chinese population. WHtR and WC show better abilities in predicting cardiometabolic multimorbidity than BMI.

Introduction

Cardiometabolic diseases, including stroke, diabetes, and heart disease, are the leading cause of deaths worldwide[1, 2]. With the rapid population aging, cardiometabolic multimorbidity, defined as the co-occurrence of 2 or more cardiometabolic diseases, has become a prominent public health concern. Remarkably, the health damages attributed to cardiometabolic multimorbidity are far more significant than a single cardiometabolic disease. It is reported that, when compared with elderly people without cardiometabolic diseases, individuals with any of cardiometabolic diseases or with any two of cardiometabolic diseases were estimated to have reduced life expectancies of 7 years and 12 years, respectively[3]. Furthermore, individuals with one cardiometabolic disease or with cardiometabolic multimorbidity also had 1.41 and 1.89 times the odds of higher mental stress than those without cardiometabolic disease, respectively[4]. However, as a major and persistent problem[5, 6], cardiometabolic multimorbidity has been quite inadequately studied, and early prevention measures need to be taken urgently.

Obesity has been acknowledged as an important risk factor for cardiometabolic diseases. Large amounts of evidence also showed that body mass index (BMI), a common measure of obesity, could predict single cardiometabolic diseases. In contrast, only a few studies reported the prospective association of BMI with

cardiometabolic multimorbidity in Europe and America[7, 8]. However, the evidence for this association remains to be further validated in Asian populations. Recently, waist circumference (WC) and waist-to-height ratio (WHtR) have been proposed to be important anthropometric indicators of abdominal obesity[9, 10], and many studies demonstrated that these two indicators were superior to BMI in predicting single cardiometabolic diseases[9–15]. Nevertheless, the relationship between WHtR, WC and cardiometabolic multimorbidity has yet to be assessed.

In this study, we investigated the longitudinal relationship between BMI, WHtR, WC, and cardiometabolic multimorbidity in the middle-aged and elderly Chinese population. Our aims are two-fold: (1) to assess the association of BMI, WHtR and WC with cardiometabolic multimorbidity; (2) to compare the predictive ability of BMI, WHtR, and WC in risk of cardiometabolic multimorbidity.

Methods

Study Design

We used data from the China Health and Retirement Longitudinal Study (CHARLS)[16]. CHARLS is a nationally representative longitudinal survey, which collects data from individuals aged 45 and above in China. A wide range of information concerning the economic standing, physical and psychological health, demographics and social networks has been collected. Anthropometric indicators and cardiometabolic diseases have also been assessed in CHARLS. The first national baseline survey of CHARLS was conducted in 2011-2012, which included 10,257 households and 17,708 individuals from 150 counties/districts and 450 villages/resident communities[17]. Participants were then followed up every 2 years. Details of the study design of CHARLS can be found in previous literature[18]. This study was approved by Biomedical Ethics Review Committee of Peking University. All participants signed informed consents.

Study Population

All participants recruited in the national baseline survey were included if they met the following criteria: (1) aged at least 45 years; (2) no history of cardiometabolic multimorbidity at baseline; (3) collected anthropometric indicators successfully; (4) successfully followed up. Finally, we included 8807 individuals without any cardiometabolic disease at baseline and 1714 individuals with one of cardiometabolic diseases at baseline (Figure 1).

WHtR, WC and BMI Measurements

BMI was calculated as weight (kg) divided by the square of height (m). WHtR was defined as WC (cm) divided by height (cm). Height and weight were measured by vertical height measuring instrument and weighing scale with bare feet and light clothes. When measuring WC, the measured personnel used a soft ruler to circle the waist horizontally at the level of the navel.

Cardiometabolic multimorbidity and outcomes

Cardiometabolic multimorbidity is defined as having two or more of the following three diseases: diabetes, stroke, and heart problems[3]. The diagnosis of cardiometabolic diseases was determined by participants' self-reported information. This study evaluated the development of cardiometabolic multimorbidity from two situations: 1) From 0 cardiometabolic disease at baseline to cardiometabolic multimorbidity (stage Ⅱ); 2) From 1 cardiometabolic disease at baseline to cardiometabolic multimorbidity (Stage Ⅲ). For the first situation, subjects who did not suffer from any of the three diseases in 2011 were included. Subsequently, people who eventually developed two or more cardiometabolic diseases during follow-up were deemed as individuals with cardiometabolic multimorbidity. For the second situation, participants having only one of the three diseases in 2011 were included, and then developing one or more new-onset cardiometabolic diseases during follow-up was defined as cardiometabolic multimorbidity.

Covariates

Covariates included sociodemographic characteristics, lifestyle factors and current disease status[19]. Sociodemographic characteristics included age (years), gender (male/female), education level (less than lower secondary education/upper secondary & vocational training/tertiary education), and residence (rural/urban). Lifestyle factors included smoking status (ever smoking/never smoking) and drinking status (ever drinking/never drinking). Current diseases (yes/no) included hypertension, cancer, lung disease, psychological problems, arthritis, dyslipidemia, liver disease, kidney disease, stomach/digestive system diseases, and asthma.

Statistical Analysis

Categorical variables were presented by frequency (percentage) and compared by the Chi-square test. Continuous data were described as median (inter-quartile range) and compared by the Wilcoxon rank sum test[20, 21].

For subsequent analyses, we converted the continuous variables into binary variables, using the cut-off values of 24kg/m² for BMI[20], 0.5 for WHtR[13], and 75 cm (women) and 85cm (men) for WC[22], respectively. Binary logistic regression model was used to access the associations of BMI, WHtR and WC with cardiometabolic multimorbidity, and the odds ratios (ORs) and 95% confidence intervals (CIs) were estimated. Net reclassification index (NRI) and integrated discrimination improvement (IDI) were calculated to compare the predictive utilities of BMI, WHtR and WC for cardiometabolic multimorbidity beyond other conventional factors[17, 23].

All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA). A two-sided *P*-value less than 0.05 was deemed statistically significant.

Results

Stage Ⅱ: From 0 cardiometabolic disease to cardiometabolic multimorbidity

A total of 8807 participants without any cardiometabolic disease at baseline were included in this stage. During a four-year follow-up, 112 (1.27%) participants were reported to have cardiometabolic multimorbidity. Participants with cardiometabolic multimorbidity were older and more likely to have higher anthropometric indicators (BMI, WHtR and WC) than those without cardiometabolic multimorbidity (all $P < 0.05$). Compared with people without cardiometabolic multimorbidity, individuals with cardiometabolic multimorbidity exhibited significantly higher prevalence of hypertension, lung disease, dyslipidemia, liver disease, kidney disease, and asthma (All $P < 0.05$) (Table 1).

Table 1
Baseline characteristics of the study population

Characteristics	Stage I (n = 8807)			Stage II (n = 1714)		
	Cardiometabolic multimorbidity			Cardiometabolic multimorbidity		
	No	Yes	<i>P</i> value	No	Yes	<i>P</i> value
N (%)	8695 (98.73)	112 (1.27)		1501 (87.57)	213 (12.43)	
Age (year)	57 (51–64)	60.5 (54–66.5)	0.0069	60 (54–67)	61 (55–67)	0.3303
Male (%)	4219 (48.52)	46 (41.07)	0.1169	628 (41.84)	83 (38.97)	0.4260
Rural (%)	5867 (67.48)	78 (69.64)	0.6265	899 (59.89)	109 (51.17)	0.0155
Education (%)						
Level I	7839 (90.16)	99 (88.39)	0.2977	1333 (88.81)	191 (89.67)	0.1188
Level II	755 (8.68)	13 (11.61)		144 (9.59)	15 (7.04)	
Level III	101 (1.16)	0 (0)		24 (1.60)	7 (3.29)	
BMI (kg/m ²)	22.81 (20.64–25.36)	24.35 (21.75–27.47)	< .0001	24.01 (21.52–26.78)	25.62 (23.21–28.35)	< .0001
WHtR	0.53 (0.47–0.58)	0.57 (0.52–0.63)	< .0001	0.55 (0.51–0.60)	0.58 (0.54–0.62)	< .0001
WC (cm)	83.90 (77.20–91.00)	90.20 (80.50–98.85)	< .0001	87.40 (80.0–94.8)	92.8 (85.0–100.0)	< .0001
Current Drinking (%)	3465 (39.88)	34 (30.36)	0.0408	508 (33.87)	69 (32.39)	0.6705
Current Smoking (%)	2832 (32.67)	34 (30.36)	0.6043	365 (24.43)	45 (21.13)	0.2909

Note: WHtR, waist-to-height ratio; WC, waist circumference; BMI, body mass index. Values were presented as n (%) or median (25th -75th percentile).

Level I— Less than lower secondary education; level II— Upper secondary or vocational training; level III— Tertiary education.

Characteristics	Stage I (n = 8807)			Stage II (n = 1714)		
Hypertension (%)	1711 (19.75)	51 (45.54)	< .0001	653 (43.59)	133 (62.44)	< .0001
Cancer (%)	64 (0.74)	2 (1.79)	0.2052	28 (1.87)	5 (2.36)	0.8274
Lung disease (%)	800 (9.21)	18 (16.07)	0.0130	232 (15.50)	42 (19.72)	0.1161
Psychological problems (%)	100 (1.15)	2 (1.79)	0.8598	26 (1.73)	2 (0.94)	0.5751
Arthritis (%)	2890 (33.28)	38 (33.93)	0.8842	670 (44.76)	94 (44.13)	0.8638
Dyslipidemia (%)	503 (5.87)	24 (21.43)	< .0001	296 (20.04)	66 (31.43)	0.0002
Liver disease (%)	274 (3.16)	8 (7.21)	0.0330	81 (5.42)	12 (5.63)	0.8967
Kidney disease (%)	432 (4.98)	11 (9.91)	0.0184	140 (9.38)	23 (10.80)	0.5093
Stomach/digestive system diseases (%)	1868 (21.51)	28 (25.00)	0.3723	464 (30.95)	61 (28.64)	0.4929
Asthma (%)	356 (4.11)	11 (9.82)	0.0099	111 (7.42)	20 (9.39)	0.3120
Note: WHtR, waist-to-height ratio; WC, waist circumference; BMI, body mass index. Values were presented as n (%) or median (25th -75th percentile).						
Level I— Less than lower secondary education; level II— Upper secondary or vocational training; level III— Tertiary education.						

During the follow-up period, 58 (1.78%) participants with BMI ≥ 24 developed cardiometabolic multimorbidity, while 54 (0.97%) participants with BMI < 24 developed cardiometabolic multimorbidity. The number (percentage) of participants with WHtR ≥ 0.5 that developed cardiometabolic multimorbidity was 92 (1.54%), while it was only 20 (0.71%) in people with WHtR < 0.5 . In addition, there were 87 (1.55%) new cardiometabolic multimorbidity cases in the group of WC ≥ 85 (men) + WC ≥ 75 (women), and 25 (0.79%) new cardiometabolic multimorbidity cases in the group of WC < 85 (men) + WC < 75 (women). In logistic regression models (Fig. 2), BMI ≥ 24 was significantly associated with increased risk of cardiometabolic multimorbidity (OR: 1.85, 95% CI: 1.27–2.68). After multivariate adjustments, the odds ratio was decreased with marginal significance (OR: 1.48, 95% CI: 0.98–2.24). In contrast, WHtR was closely related to risk of cardiometabolic multimorbidity (OR: 2.19, 95% CI: 1.35–3.55). Moreover, the association between WHtR and risk of cardiometabolic multimorbidity persisted after multivariate adjustments (OR: 1.76, 95% CI: 1.05–2.97). Likewise, the odds of developing cardiometabolic multimorbidity in the high WC group was about twice as high as that in the lower WC group (OR: 1.98,

95% CI: 1.27–3.10). After multivariate adjustments, participants with high WC was 1.77 times (OR: 1.77, 95% CI: 1.05–2.97) more likely to have cardiometabolic multimorbidity.

The capacities of BMI, WHtR and WC for predicting cardiometabolic multimorbidity were further evaluated. The addition of BMI, WHtR or WC to model 1 (adjusted for age, smoking, gender and hypertension) significantly improved the discriminatory power, except for the IDI value for BMI. The estimates (95% CI) of NRI and IDI were 0.3077 (0.0945–0.4929) and 0.0009 (-0.0001–0.0019) for BMI, 0.3248 (0.1399–0.5097) and 0.0029 (0.0029–0.0048) for WHtR, and 0.3524 (0.1685–0.5364) and 0.0028 (0.0009–0.0047) for WC, respectively. Likewise, after adding BMI to model 2, the IDI value of BMI was still not statistically significant (IDI: 0.0014, 95% CI: -0.0004–0.0032). By contrast, adding WHtR and WC to model 2 brought about a significant improvement of the predictive utility in cardiometabolic multimorbidity, with the estimates (95% CI) of NRI and IDI being 0.3211 (0.1346–0.5076) and 0.0052 (0.0014–0.009) for WHtR, and 0.3364 (0.1504–0.5225) and 0.005 (0.0013–0.0086) for WC (Table 2).

Table 2
NRI and IDI of BMI, WHtR and WC for prediction of cardiometabolic multimorbidity

Model	NRI		IDI	
	Estimate(95% CI)	P value	Estimate(95% CI)	P value
Stage I				
Model 1 ^a	Reference	–	Reference	–
Model 1 + BMI	0.3077 (0.1224–0.4929)	0.0012	0.0009 (-0.0001–0.0019)	0.0787
Model 1 + WHtR	0.3248 (0.1399–0.5097)	< .0001	0.0029 (0.0009–0.0048)	0.0035
Model 1 + WC	0.3524 (0.1685–0.5364)	0.0002	0.0028 (0.0009–0.0047)	0.0043
Model 2 ^b	Reference	–	Reference	–
Model 2 + BMI	0.2746 (0.0871–0.4622)	0.0042	0.0014 (-0.0004–0.0032)	0.1254
Model 2 + WHtR	0.3211 (0.1346–0.5076)	0.0008	0.0052 (0.0014–0.009)	0.0074
Model 2 + WC	0.3364 (0.1504–0.5225)	0.0005	0.0050 (0.0013–0.0086)	0.0074
Stage 2				
Model 1 ^a	Reference	–	Reference	–
Model 1 + BMI	0.2643 (0.1215–0.4070)	0.0003	0.0092 (0.0042–0.0142)	0.0003
Model 1 + WHtR	0.2522 (0.1094–0.3950)	0.0006	0.0126 (0.0068–0.0184)	< .0001
Model 1 + WC	0.3152 (0.1733–0.4572)	< .0001	0.0187 (0.0116–0.0259)	< .0001
Model 2 ^b	Reference	–	Reference	–
Model 2 + BMI	0.2261 (0.0813–0.3708)	0.0023	0.0060 (0.0017–0.0102)	0.0058
Model 2 + WHtR	0.1875 (0.0426–0.3324)	0.0115	0.0089 (0.0039–0.0138)	0.0005
Model 2 + WC	0.2893 (0.1454–0.4333)	< .0001	0.0140 (0.0078–0.0202)	< .0001
Note: BMI, body mass index; WHtR, waist-to-height ratio; WC, waist circumference; CI, confidence interval.				
^a Model 1 included age, smoking, gender and hypertension.				
^b Model 2 included age, gender, education level, residence, smoking, drinking, hypertension, cancer, lung disease, psychological problems, arthritis, dyslipidemia, liver disease, kidney disease, Stomach/digestive system diseases, and asthma.				

Stage Ⅱ: From 1 Cardiometabolic Disease To Cardiometabolic Multimorbidity

Among 1714 participants in stage Ⅱ, 213 (12.43%) participants were classed as having cardiometabolic multimorbidity and 1501 (87.57%) participants were defined as non-cardiometabolic multimorbidity. Likewise, people with cardiometabolic multimorbidity had higher BMI, WHtR and WC, and possessed higher prevalence of hypertension and dyslipidemia (all $P < 0.05$) (Table 1).

During follow-up, incidence rates of cardiometabolic multimorbidity in the high BMI, WHtR and WC groups were 15.41% (137), 14.08% (193) and 14.21% (189), respectively, while incidence rates in the low BMI, WHtR and WC groups were 9.21% (76), 5.83% (20) and 6.25% (24), respectively. Furthermore, the risk of having cardiometabolic multimorbidity was most pronounced for WC (OR: 2.07, 95% CI: 1.28–3.34), followed by WHtR (OR: 2.04, 95% CI: 1.24–3.35) and BMI (OR: 1.47, 95% CI: 1.06–2.04) (Fig. 2).

NRI and IDI values were applied to compare the predictive abilities of BMI, WHtR and WC on risk of cardiometabolic multimorbidity. The NRI and IDI values showed that WC was advantageous over BMI and WHtR in predicting cardiometabolic multimorbidity among individuals with only one cardiometabolic disease at baseline. Adding BMI, WHtR and WC to model 1 improved patient classification by 26.43% (12.15–40.70%), 25.22% (10.94–39.59%) and 31.52% (17.33–45.72%), respectively, and probabilistic difference of suffering cardiometabolic multimorbidity between cases and controls by 0.92% (0.42–1.42%), 1.26% (0.68–1.84%), and 1.87% (1.16–2.59%), respectively. Likewise, in model 2, the NRI and IDI (95% CI) were 0.2261 (0.0813–0.3708) and 0.006 (0.0017–0.0102) for BMI, 0.1875 (0.0426–0.3324) and 0.0089 (0.0039–0.0138) for WHtR, 0.2893 (0.1454–0.4333) and 0.014 (0.0078–0.0202), respectively (Table 2).

Discussion

The present study investigated the prospective association of BMI, WHtR and WC with cardiometabolic multimorbidity in a nationally representative cohort. Our results showed that BMI, WHtR and WC were all independently associated with increased risk of cardiometabolic multimorbidity among the middle-aged and elderly Chinese population. Moreover, compared with BMI, WHtR and WC exhibited better predictive utilities in future cardiometabolic multimorbidity.

Cardiometabolic multimorbidity, as a growing problem, poses a major challenge to health care systems throughout the world. Previous studies have suggested that cardiometabolic multimorbidity is much more harmful than a single cardiometabolic disease. For example, compared to the absence of any of the three cardiometabolic diseases, the hazard ratio (HR) for all-cause mortality was about twice in any one of these diseases, 4 times in any two of these diseases, and 7 times in the presence of all three diseases[3]. In view of the serious harm of cardiometabolic multimorbidity, early predictive indicators need to be discovered urgently. However, quite limited studies have investigated the associations of easy-to access anthropometric indicators, such as BMI, WHtR and WC, with risk of cardiometabolic

multimorbidity. To the best of our knowledge, there are only two studies exploring the link between BMI and cardiometabolic multimorbidity[7, 8]. The study by Kivimäki et al. involving 16 longitudinal research databases and 120,813 subjects suggested that the risk of cardiometabolic multimorbidity increased as BMI increased[8]. This comprehensive analysis indicated that compared with healthy-weight individuals, overweight and obesity individuals ($BMI \geq 24$) had twice the risk of developing cardiometabolic multimorbidity. The OR values between this study and ours are similar, indicating the predictive power of BMI. However, the Asian population has not been included in this study, and our study can be a supplement in this regard. Another study recruiting 8270 subjects showed that the hazard ratio for overweight/obesity was 1.19 times (95% CI: 1.00–1.43) higher for developing cardiometabolic multimorbidity from 1 baseline cardiometabolic disease than individuals with healthy weight.

WC, as an abdominal obesity measurement indicator, has been supported as an obesity-related health risk indicator for both Western and Asian populations[24–26]. Previous studies have suggested that WC has greater predictive power for risk of cardiometabolic diseases than BMI[9, 27]. Furthermore, a large amount of evidence has also supported that WHtR was more effective than BMI in predicting coronary heart disease, stroke and diabetes[9, 12–14, 21, 28, 29]. Remarkably, our study also found that WHtR and WC were independent predictors of cardiometabolic multimorbidity. Moreover, WHtR and WC were demonstrated to possess higher predictive abilities on risk of cardiometabolic multimorbidity than BMI in the current study. This phenomenon may be explained by the following reasons. First of all, BMI can only be used to measure the total body fat and cannot represent the body fat distribution[30]. The susceptibility of cardiometabolic diseases may depend on the difference of regional body fat distribution and the ability of subcutaneous adipose tissue[31]. Moreover, WC reflects body fat ratio more accurately than BMI, and it may play an important role in the early development of metabolic syndrome[32, 33]. A recent systematic review demonstrated that compared with BMI, WC increased the ability to discriminate adverse cardiometabolic risk outcomes by 3%[29]. In addition, WHtR has been suggested to be less affected by race, age and gender and be relatively more stable[9, 11, 34]. People with the same BMI might have different risks of cardiometabolic diseases[31]. Even among people with normal BMI, those with high WHtR are more likely to suffer from cardiometabolic diseases. Notably, about 35% of men and 14% of women with high WHtR would be missed if screened by BMI only, which could bring serious consequences for cardiometabolic disease prevention[35]. Considering that WHtR and WC have better predictive power in cardiometabolic multimorbidity than BMI, screening by WHtR and WC might be applicable in future practice.

The exact mechanisms underlying the association between BMI, WHtR, WC, and cardiometabolic multimorbidity remain to be illuminated, but insulin resistance and ectopic fat deposition may be the main contributors. Adipose tissue produces a large amount of bioactive mediators, which leads to insulin resistance. Insulin resistance may cause cardiometabolic diseases in the following ways. First, in a state of insulin resistance, inflammation occurs in the body, which eventually leads to atherosclerosis[36]. Second, insulin resistance affects the production of apolipoprotein A1 (apoA-Ⅰ) or the liver secretion of high-density lipoprotein (HDL), which could be a trigger for metabolic syndrome[37]. Third, insulin resistance would obstruct normal heart function through inhibiting metabolic pathways and over-

stimulating growth factors[38]. In addition, ectopic fat deposition triggers a pathological metabolic response, increasing the risk of metabolic diseases[31]. Excess free fatty acids are produced outside the fat storage tissue, and transferred to ectopic sites, including the viscera, heart, and vasculature, ultimately leading to cardiometabolic diseases[39].

There are several merits in this study. Our study is the first to investigate the association of WHtR and WC with risk of cardiometabolic multimorbidity. Moreover, WHtR and WC were shown to be advantageous in predicting cardiometabolic multimorbidity than BMI. In addition, the two-stage strategy to assess cardiometabolic multimorbidity could provide mutual validation and increase the reliability of the associations. Limitations should be noted as well. First, our research was based on the four-year follow-up data, preventing the assessments of a long-term association. Second, the cardiometabolic diseases included in this study were self-reported. However, self-reported cardiometabolic diseases have been proved to be highly reliable in large-scale epidemiological studies[40].

Conclusions

In the middle-aged and elderly Chinese population, WHtR, WC and BMI were found to be independent predictors of cardiometabolic multimorbidity. In addition, WHtR and WC exhibited better predictive power in future cardiometabolic multimorbidity than BMI. Our findings highlight the significance of screening and interventions of high-risk individuals through easy-to-access and cost-effective tools, such as WHtR and WC, for the prevention of cardiometabolic multimorbidity.

Abbreviations

WHtR, waist-to-height ratio; WC, waist circumference; BMI, body mass index; CHARLS, China Health and Retirement Longitudinal Study; ORs, odds ratios; CIs, confidence intervals; NRI, net reclassification index; IDI, integrated discrimination improvement.

Declarations

Ethics approval and consent to participate

CHARLS was approved by Biomedical Ethics Review Committee of Peking University, and all participants signed informed consents.

Consent for publication

Not applicable.

Availability of data and materials

The data used and analyzed in this study are publicly available from the China Health and Retirement Longitudinal Study (<http://charls.pku.edu.cn/zh-CN>).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CK conceived and designed the research; YL and SL wrote the manuscript; and GL, YQ and YW performed the data analysis. All authors contributed to the interpretations of the findings. All authors reviewed the manuscript.

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Figures

Figure 1

Flowchart of participant selection

0 disease to cardiometabolic multimorbidity

1 disease to cardiometabolic multimorbidity

Figure 2

Association of BMI, WHtR and WC with risk of cardiometabolic multimorbidity