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Relationship between obesity indicators and hypertension–diabetes comorbidity among adults: a population study from Central China

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ABSTRACT

Objective To identify the relationship between obesity indicators and hypertension–diabetes comorbidity (HDC) among adults in central China.

Design and setting A cross-sectional study was conducted from 1 June 2015 to 30 September 2018 in 11 districts of Hubei Province, China.

Participants A total of 29 396 participants aged 18 years or above were enrolled in the study. 2083 subjects with missing data were excluded. Eventually, 25 356 participants were available for the present analysis.

Main outcome measures Data were subjected to univariable and multivariable logistic regression to examine the association between obesity indicators (body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR)) and HDC prevalence. Crude odds ratio and adjusted OR (AOR) with associated 95% CI were calculated.

Results Overall, 2.8% of the respondents had HDC. The odds of HDC prevalence increased with the BMI of the participants (18.5≤BMI (kg/m^2)≤23.9—1; 24≤BMI (kg/m^2)≤26.9—AOR: 5.66, 95% CI: 4.25 to 7.55; BMI (kg/m^2)≥27—AOR: 7.96, 95% CI: 5.83 to 10.87). The risk of HDC also increased with the WHtR of participants (WHtR≤P_{25}—1; P_{25}≤WHtR≤P_{50}—AOR: 1.73, 95% CI: 1.10 to 2.71; P_{50} ≤WHtR≤P_{75}—AOR: 2.51, 95% CI: 1.60 to 3.92; WHtR≥P_{75}—AOR: 3.22, 95% CI: 2.01 to 5.16). Stratified analysis by gender showed that high BMI and WHtR were risk factors of HDC in males and females. However, the odds of HDC prevalence increased only when WHtR≥P_{75} in males, whereas the probability of HDC increased when WHtR≥ P_{25} in females.

Conclusion High BMI and WHtR can increase the risk of HDC among Chinese adults. Reasonable control of BMI and WHtR may be beneficial in preventing HDC. Females should focus on maintaining an optimal WHtR earlier.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study is the first to explore the relationship between obesity indicators and hypertension–diabetes comorbidity among adults in Central China.
- ⇒ The database consists of data of random individuals from a large sample generated via a multistage stratified sampling approach.
- ⇒ Response bias is inevitable because some of the data are self-reported by participants.
- ⇒ A cross-sectional study design prohibits drawing conclusions about causality.

INTRODUCTION

With the development of society and economy, obesity has become a common disease, which seriously affects human health.[1] The number of people with this disease is gradually increasing because of the change in diet structure, lack of physical activities and unhealthy lifestyle.[2] In the USA, about 38.9% adults had obesity.[3] In Europe, the prevalence of obesity is 18%–30%.[4] The prevalences of central obesity, general obesity and compound obesity among individuals aged 18–65 years in China reached 30.3%, 0.9% and 10.3% in 2011, respectively.[5] Economic globalisation not only has a great impact on social and economic development, but also further aggravates the prevalence of obesity.[6]

Hypertension and diabetes are two related metabolic disorders. Diabetes is a significant predictor of hypertension, and hypertension is a significant predictor of diabetes. Insulin resistance (IR) is a common feature of prehypertension and pre-diabetes, which are early stages that can develop into hypertension and diabetes.[7] Hypertension–diabetes comorbidity (HDC) refers to the coexistence of two diseases. HDC is closely related to IR. Castro *et al* showed that obesity is the main cause of IR.[8] Therefore, obesity is likely correlated with HDC. Because of insufficient sample size, many studies were restricted to either hypertension or diabetes, and few researchers have looked at the obesity on the risk of HDC. Moreover, the relationship between obesity and HDC was also different in different races and countries.[9 10]

China is a country with a vast territory, with the majority of Han population different from western countries. Different places have different levels of economic development and different lifestyles of residents. The prevalence of hypertension and diabetes varies geographically.[11 12] Therefore, the prevalence of HDC may also vary geographically. So far, no large sample studies in China, especially in Central China, have specifically explored the relationship between obesity and HDC, but more focused on a single disease.

Body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) are all indicators of obesity. By comparison, BMI and WC are most commonly used in research. Garrow pointed out that BMI as a single indicator lacks the prediction ability to measure the risk of obesity for cardiovascular disease.[13] In addition, the cut-off of BMI and WC for judging systemic obesity and abdominal obesity are different in China and western countries. Conclusions drawn in western populations may not be applicable to Chinese populations.

Therefore, the relationship between obesity indicators (BMI, WC and WHtR) and HDC should be further studied in Chinese population. This study was conducted to explore the prevalence of HDC among adults of Central China and clarify the relationship between HDC and obesity indicators, namely, BMI, WC and WHtR.

METHODS

Study design

With the assistance of Centers for Disease Control and Prevention in each administrative districts, a population-based cross-sectional questionnaire survey was conducted from 1 June 2015 to 30 September 2018 in 11 districts of Hubei Province, China. The following multistage stratified sampling approach was applied to each district: (1) six towns were randomly selected from each district; (2) six communities or villages were randomly chosen from each town; (3) at least 60 families were randomly selected from each community or villages; and (4) one resident over 18 years old was randomly chosen from each family.

Study population

To be included in the study, residents were required to meet the following criteria: (1) age ≥18 years and (2) informed and agreed to participate in the survey. Adults with allopathy, consciousness disorder or severe cognitive impairment were excluded from this study. The following formula was used to calculate the sample size: $n = Z^2PQ/d^2$, where Z=1.96 at 95% CI, p=prevalence of HDC, Q=1−P and d=absolute allowable error.[14] In our study, the prevalence of HDC was presumed to be 5.2% based on a previous study[15] and d=0.1. The sample size yielded was at least 2083 in each district. A total of 29 396 adults were selected. A total of 4040 participants with missing data were excluded. Of these, 1853 were males and 2187 were females; 481 people aged 18–39, 1523 people aged 40–59 and 2036 people aged ≥60 The number of participants excluded for missing data varied from 210 to 450 in each region. The final sample was reduced to 25 356 participants (with an effective response rate of 86.3%).

Measures

The following data were collected through face-to-face interviews conducted in the participant's homes, by using a self-designed questionnaire, which was designed according to the contents of the Monitoring of Chronic Diseases and Their Risk Factors (2013) working Manual issued by the Chinese Center for Disease Control and Prevention.[16]

Demographic characters included age (years), gender, education status (illiterate or some primary school, primary school graduate or some junior high school, junior high school graduate or some senior high school, senior high school graduate or some college, college graduate or above), marital status (single, married, divorced/widowed/separated), occupation and per capita family monthly income (PCFMI; <1000 RMB, 1000–1500 RMB, 1500–2000 RMB and ≥2000 RMB).

As for behavioural risk factors, the participants were invited to answer questions on their current status of smoking (active or passive smoking), alcohol drinking, work intensity, physical exercise, daily static behaviour time (including sitting work, learning, reading, watching television, using computer, rest and other static behaviour time except sleeping time) and daily salt intake. Smoking status was determined by asking the participants: 'Are you currently a smoker? Are you a passive smoker?' Persons who replied that they smoked 'everyday,' on 'some days' or 'passive smoker' were classified as current smokers. Those who replied 'not a smoker or passive smoker' were classified as non-current smokers.

The awareness of knowledge related to chronic diseases was assessed with four questions: (1) 'do you know if salt consumption can affect health? (Persons who answered 'no' or 'don't know' were classified as they do not have the knowledge)'; (2) 'Do you know the standard of daily salt intake per person? (Persons who answered 'no' or 'don't know' were classified as they do not have the knowledge)'; (3) 'Do you know the standard of daily oil intake per person? (Persons who answered 'no' or 'don't know' were classified as they do not have the knowledge)'; (4) 'Do you know the criteria for people at a high risk of chronic disease?' (The criteria were as follows: blood pressure, 130–139/85–89 mm Hg; current smokers; 6.1 mmol/L≤fasting blood–glucose<7.0 mmol/L; 5.2 mmol/L≤serum total cholesterol<6.2 mmol/L; participants who correctly answered at least one of these criteria were classified as 'Yes').

The actual height and weight of all respondents were measured using an ultrasonic height sensor and their BMI was computed. WCs were measured using an non-elastic tape. WHtRs were computed from WC and height of the respondents. BMI was divided into four categories: thin (<18.5 kg/m^2), moderate (18.5 kg/m^2 to 23.9 kg/m^2), overweight (24.0 kg/m^2 to 26.9 kg/m^2) and obese

(>27.0 kg/m^2).[17] WC was divided into two categories: males ≧90 cm and females ≧85 cm.[18]

The blood pressure was measured three times by using mercury sphygmomanometer with the subject in the sitting position and the average was used as the final value. Hypertension was defined as a mean systolic blood pressure of at least 140 mm Hg, or a diastolic blood pressure of at least 90 mm Hg, or current treatment with antihypertensive medication or a self-reported diagnosis of hypertension.[19] Blood glucose was measured using Omron glucometer. The day before the measurement, informed consent was obtained by telephone and participants were told to stay on an empty stomach for 12 hours. Participants with fasting plasma glucose of >7.0 mmol/L or those who were receiving antidiabetic medications were diagnosed with diabetes mellitus.[20]

Pilot study

In order to validate the questionnaire, a pilot study was conducted on a small group of 40 participants, who were requested to complete it and to point out any question that they thought unclear. The necessary modifications were made in the final questionnaire. Cronbach's alpha was calculated to assess the internal consistency of the questionnaire, and it was found to be 0.78.

Data collection procedure

Those who met the inclusion criteria were informed of the study and asked if they were willing to participate or provide an informed consent. The targeted individuals were asked to answer the questionnaires independently and anonymously. The participants were interviewed by trained interviewers if they requested assistance for completing the survey (eg, participants with dyslexia). Lastly, the completed questionnaires were checked by qualified investigators (ie, graduate students specifically trained to carry out data collection for this study) to ensure the completeness of the questionnaires with immediate follow-up with participants needing further information, as needed.

Quality control

Our targeted individuals were asked to answer the questionnaires anonymously (without indicating personal details) and fill out the survey questions independently based on their inner true feelings. Prior to the implementation of the survey, the investigators were trained to use the unified guidance language. During the implementation of the survey, the purpose and significance of this study were clearly explained to the participants. The finished questionnaires were checked by research members to ensure the effectiveness of the questionnaires, that is, 5% of the respondents in the survey sites were randomly checked, and the consistent rate of questionnaire filling should be greater than 95%.

Statistical analysis

Data were entered to EpiData V.3.1 and exported to Stata V.15.1 for analysis.[21] The reference 25th (P_{25}), 50th (P_{50}) and 75th (P_{75}) percentiles were constructed for WC in accordance with previously described methods.[22] Data analysis was performed in two steps. First, categorical and metric variables were summarised via initial descriptive analysis. Frequencies with proportions and means with SDs were presented. Variable's assignment and dummy variables are presented in Table A1 (online supplemental file 1). Second, univariate and multivariate analyses were conducted via binary logistic regression to identify the presence of an association between the obesity indicators and HDC of respondents. Crude odds ratio (COR) and adjusted OR (AOR) with associated 95% CI were reported. Data with p<0.05 were considered statistically significant.

Patient and public involvement

No patients or members of the public were involved in the design or planning of the study.

RESULTS

Descriptions of sample demographic information

This study sample consisted of a total of 25 356 subjects, which included 12 214 (48.17%) males and 13 142 (51.8%) females. The largest age group composed of individuals aged 18–39 years (40%) followed by those aged 40–59 years (34.4%). The proportions of males and females aged 18–39 years were 39.42% (5315/13 142) and 40.44% (4815/12 214), respectively. Overall, 84.1% of the participants (21 328) were married. Furthermore, 15 026 respondents (59.26%) had a junior high school education or higher. Most people worked in businesses or services (35.3%), and 34.1% of the participants had PCFMI ranging from 1500 Yuan to 2000 Yuan (RMB). The majority of the respondents were smoking or passively smoking (82.7%), drinking (73.7%), having a low intensity of work (49.3%), having less than 4 hours of static activity per day (64.8%), having awareness of the health effects of salt intake (63%), having salt intake of >18 g per day (53.4%), not engaging in exercise (80.9%) and not having the knowledge about the standard of daily salt intake per person (79.2%). Only 20.8% and 18.0% of the participants knew the standards of daily salt and oil intake. Only 27.8% of the participants were aware of the risk standard of chronic diseases. The largest BMI group was 18.5–23.9 kg/m^2 (59.2%), and most individuals had a normal WC (53.4%). The participants were classified into four groups based on WHtR, <P_{25} (0.46), P_{25}–< P_{50}(0.50), P_{50}–< P_{75} (0.55), ≧P_{75}, accounting for 25.3%, 24.9%, 25.8% and 24%, respectively. The distribution of the participant's general characteristics differed in terms of the prevalence of HDC (p<0.05). The prevalence of HDC among the adults was 2.8%. The participants' general sociodemographic characteristics are summarised in table 1.

Univariate and multivariate analyses of the association between obesity indicators and the prevalence of HDC

COR and AOR were obtained from univariate logistic regression and multivariable logistic regression, respectively, to

Table 1 General characteristics of the survey participants

Variable	N (%)	HDC (n=713) n (%)	Non-HDC (n=24 643) n (%)	χ^2	P
Gender				18.48	<0.001
Male	12 214 (48.2)	400 (56.1)	11 814 (47.9)		
Female	13 142 (51.8)	313 (43.9)	12 829 (52.1)		
Age (years)				386.08	<0.001
18–39	10 130 (40.0)	34 (4.8)	10 096 (41.0)		
40–59	8717 (34.4)	361 (50.6)	8356 (33.9)		
≧60	6509 (25.7)	318 (44.6)	6191 (25.1)		
Marital status				191.61	<0.001
Unmarried	2012 (7.9)	77 (10.8)	1935 (7.8)		
Married	21 328 (84.1)	485 (68.0)	20 843 (84.6)		
Divorce/widowhood/separated	2016 (8.0)	151 (21.2)	1865 (7.6)		
Education status				361.08	<0.001
Illiterate	2807 (11.1)	232 (32.5)	2575 (10.4)		
Primary school	7523 (29.7)	179 (25.1)	7344 (29.8)		
Junior high school	8515 (33.6)	210 (29.5)	8305 (33.7)		
High school	3368 (13.3)	45 (6.3)	3323 (13.5)		
University or above	3143 (12.4)	47 (6.6)	3096 (12.6)		
Occupation				29.6	<0.001
Management	4943 (19.5)	194 (27.2)	4749 (19.3)		
Professional	3923 (15.5)	109 (15.3)	3814 (15.5)		
Business or services worker	8944 (35.3)	213 (29.9)	8731 (35.4)		
Agricultural worker	7546 (29.7)	197 (27.6)	7349 (29.8)		
PCFMI (RMB)				45.94	<0.001
<1000	6074 (24.0)	208 (29.2)	5866 (23.8)		
1000–1500	8004 (31.6)	274 (38.4)	7730 (31.4)		
1500–2000	8639 (34.1)	165 (23.1)	8474 (34.4)		
≥2000	2639 (10.4)	66 (9.3)	2573 (10.4)		
Smoking					
Yes	20 972 (81.5)	311 (43.6)	20 661 (83.8)	783.97	<0.001
No	4384 (23.1)	402 (56.4)	3982 (16.2)		
Drinking				131.8	<0.001
Yes	6681 (26.3)	321 (45.0)	6360 (25.8)		
No	18 675 (73.7)	392 (55.0)	18 283 (74.2)		
Work intensity				3.00E+03	<0.001
High	1428 (5.6)	370 (51.9)	1058 (4.3)		
Median	11 429 (45.1)	277 (38.9)	11 152 (45.3)		
Low	12 499 (49.3)	66 (9.3)	12 433 (50.4)		
Daily static behaviour time (hours)				467.72	<0.001
<4	16 427 (64.8)	190 (26.7)	16 237 (65.9)		
≧4	8929 (35.2)	523 (73.3)	8406 (34.1)		
Whether know salt consumption can affect health				144.55	<0.001
Yes	15 962 (63.0)	296 (41.5)	15 666 (63.6)		
No	9394 (37.0)	417 (58.5)	8977 (36.4)		
Daily salt intake (g)				23.47	<0.001

Continued

 Wu W, *et al*. *BMJ Open* 2022;**12**:e052674. doi:10.1136/bmjopen-2021-052674

Table 1 Continued

Variable	N (%)	HDC (n=713) n (%)	Non-HDC (n=24643) n (%)	χ^2	P
<6	1713 (6.8)	25 (3.5)	1688 (6.8)		
6–12	2055 (8.1)	37 (5.2)	2018 (8.2)		
12–18	8056 (31.8)	231 (32.4)	7825 (31.8)		
>18	13532 (53.3)	420 (58.9)	13112 (53.2)		
Physical exercise				19.71	<0.001
Yes	4833 (19.1)	90 (12.6)	4743 (19.3)		
No	20523 (80.9)	623 (87.4)	19900 (80.7)		
Whether know the standard of daily salt intake				20.5	<0.001
Yes	5277 (20.8)	100 (14.0)	5177 (21.0)		
No	20079 (79.2)	613 (86.0)	19466 (79.0)		
Whether know the standard of daily oil intake				5.37	0.02
Yes	4568 (18.0)	105 (14.7)	4463 (18.1)		
No	20788 (82.0)	608 (85.3)	20180 (81.9)		
WC				276.58	<0.001
Normal	13528 (53.4)	162 (22.7)	13366 (54.2)		
Abnormal	11828 (46.7)	551 (77.3)	11277 (45.8)		
BMI (kg/m^2)				682.87	<0.001
<18.5	2304 (9.1)	29 (4.1)	2275 (9.2)		
18.5–23.9	15023 (59.3)	174 (24.4)	14849 (60.3)		
24–26.9	5816 (22.9)	290 (40.7)	5526 (22.4)		
≧27	2213 (8.7)	220 (30.8)	1993 (8.1)		
Whether know the risk standard of chronic diseases				33.43	<0.001
Yes	7048 (27.8)	130 (18.2)	6918 (28.1)		
No	18308 (72.2)	583 (81.8)	17725 (71.9)		
WHtR				417.81	<0.001
<P25	6421 (25.3)	58 (8.1)	6363 (25.8)		
P25–<P50	6307 (24.9)	72 (10.1)	6235 (25.3)		
P50–<P75	6553 (25.8)	202 (28.3)	6351 (25.8)		
≧P75	6075 (24.0)	381 (53.5)	5694 (23.1)		

BMI, body mass index; HDC, hypertension–diabetes comorbidity; PCFMI, per capita family monthly income; WC, waist circumference; WHtR, waist-to-height ratio.

identify the association between the obesity indicators and prevalence of HDC (table 2). Univariate and multivariate analyses showed that the participants with characteristics of 24≤BMI (kg/m^2)≤26.9 (AOR=5.66, 95% CI=4.25 to 7.55) and BMI (kg/m^2)≥27 (AOR=7.96, 95% CI=5.83 to 10.87) were more vulnerable to HDC than those with 18.5≤BMI (kg/m^2)≤23.9. The groups with characteristics of P_{25}≤WHtR<P_{50} (AOR=1.73, 95% CI=1.10 to 2.71), P_{50}≤WHtR<P_{75} (AOR=2.51, 95% CI=1.60 to 3.92) and WHtR≥P_{75} (AOR=3.22, 95% CI=2.01 to 5.16) were more likely to suffer from HDC than those with WHtR<P_{25}.

Stratified analysis was conducted in our study to understand the differences in the association of BMI, WC, WHtR and HDC prevalence in different gender groups. Univariate and multivariable logistic regression models reported that a higher proportion of male participants with 24≤BMI (kg/m^2)≤26.9 (AOR=7.39, 95% CI=4.88 to 11.19), participants with BMI (kg/m^2)≥27 (AOR=12.19, 95% CI=7.80 to 19.07) and participants with WHtR≥P_{75} (AOR=2.27, 95% CI=1.21 to 4.26) had HDC (table 3). The results of univariate and multivariate analysis in female groups are shown in table 4. The proportions of the participants with HDC were higher in individuals with 24≤BMI (kg/m^2)≤26.9 (AOR=4.69, 95% CI=2.71 to 8.11) and BMI (kg/m^2)≥27 (AOR=6.08, 95% CI=3.09 to 11.93) than in individuals with 18.5≤BMI (kg/m^2)≤23.9. The groups with characteristics of P_{25}≤WHtR<P_{50} (AOR=3.27, 95% CI=1.33 to 8.02), P_{50}≤WHtR<P_{75} (AOR=3.00, 95% CI=1.21 to

Table 2 Logistic regression analysis of BMI, WC, WHtR associated with HDC prevalence

Variable	Crude OR (95% CI)	P value	Adjusted OR (95% CI)	P value
BMI (kg/m^2)				
18.5–23.9	Reference	–	Reference	–
<18.5	1.09 (0.73 to 1.62)	0.677	1.45 (0.92 to 2.31)	0.112
24–26.9	4.48 (3.70 to 5.42)	<0.001	5.66 (4.25 to 7.55)	<0.001
≧27	9.42 (7.68 to 11.56)	<0.001	7.96 (5.83 to 10.87)	<0.001
WC				
Normal	Reference	–	Reference	–
Abnormal	4.03 (3.38 to 4.81)	<0.001	1.20 (0.86 to 1.66)	0.288
WHtR				
$<P_{25}$	Reference	–	Reference	–
P_{25}–$<P_{50}$	1.27 (0.89 to 1.79)	0.182	1.73 (1.10 to 2.71)	0.017
P_{50}–$<P_{75}$	3.49 (2.60 to 4.68)	<0.001	2.51 (1.60 to 3.92)	<0.001
$\geqq P_{75}$	7.34 (5.56 to 9.70)	<0.001	3.22 (2.01 to 5.16)	<0.001

As for the adjusted OR, adjustments were made for gender, age, marital status, education status, occupation, PCFMI, smoking, drinking, work intensity, daily static behaviour time, whether know salt consumption will affect health, daily salt intake, physical exercise, whether know the daily salt intake standard, whether know the daily oil intake standard and whether know the risk standard of chronic diseases.
BMI, body mass index; HDC, hypertension–diabetes comorbidity; PCFMI, per capita family monthly income; WC, waist circumference; WHtR, waist-to-height ratio.

7.47) and WHtR$\geq P_{75}$ (AOR=4.53, 95% CI=1.74 to 11.79) were more likely to suffer from HDC than those with WHtR$< P_{25}$.

DISCUSSION

HDC is closely related to the progression of cardiovascular disease, stroke, kidney disease and diabetic retinopathy; it also accounts for the increased risk of general disability and premature mortality.[23 24] HDC and other related diseases severely consume medical and social resources and impose a heavy economic burden on families and countries. Identifying the factors that may be related to hypertension is the premise of taking targeted measures to prevent hypertension. This study is the first one to involve a large sample to explore the relationship between multiple obesity indicators and HDC among adults in Central China.

Table 3 Logistic regression analysis of BMI, WC, WHtR associated with HDC prevalence in male adults

Variable	Crude OR (95% CI)	P value	Adjusted OR (95% CI)	P value
BMI (kg/m^2)				
18.5–23.9	Reference	–	Reference	–
<18.5	1.71 (0.82 to 3.54)	0.151	0.62 (0.27 to 1.40)	0.251
24–26.9	8.19 (4.01 to 16.74)	<0.001	7.39 (4.88 to 11.19)	<0.001
≧27	25.52 (12.49 to 52.15)	<0.001	12.19 (7.80 to 19.07)	<0.001
WC				
Normal	Reference	–	Reference	–
Abnormal	3.75 (3.01 to 4.67)	<0.001	1.09 (0.70 to 1.70)	0.70
WHtR				
<P25	Reference	–	Reference	–
P_{25}–$<P_{50}$	0.96 (0.60 to 1.54)	0.871	1.09 (0.60 to 1.99)	0.78
P_{50}–$<P_{75}$	3.18 (2.16 to 4.69)	<0.001	1.59 (0.88 to 2.85)	0.12
$\geqq P_{75}$	9.18 (6.37 to 13.23)	<0.001	2.27 (1.21 to 4.26)	0.011

As for the adjusted OR, adjustments were made for age, marital status, education status, occupation, PCFMI, smoking, drinking, work intensity, daily static behaviour time, whether know salt consumption will affect health, daily salt intake, physical exercise, whether know the daily salt intake standard, whether know the daily oil intake standard and whether know the risk standard of chronic diseases.
BMI, body mass index; HDC, hypertension–diabetes comorbidity; PCFMI, per capita family monthly income; WC, waist circumference; WHtR, waist-to-height ratio.

Table 4 Logistic regression analysis of BMI, WC, WHtR associated with HDC prevalence in female adults

Variable	Crude OR (95% CI)	P value	Adjusted OR (95% CI)	P value
BMI (kg/m^2)				
18.5–23.9	Reference	–	Reference	–
<18.5	0.62 (0.38 to 0.99)	0.046	1.36 (0.68 to 2.71)	0.383
24–26.9	2.58 (1.62 to 4.10)	<0.001	4.69 (2.71 to 8.11)	<0.001
≧27	2.75 (1.65 to 4.58)	<0.001	6.08 (3.09 to 11.93)	<0.001
WC				
Normal	Reference	–	Reference	–
Abnormal	5.31 (3.90 to 7.24)	<0.001	1.21 (0.61 to 2.40)	0.580
WHtR				
<P25	Reference	–	Reference	–
P_{25}–< P_{50}	1.73 (1.03 to 2.91)	0.038	3.27 (1.33 to 8.02)	0.010
P_{50}–< P_{75}	3.89 (2.47 to 6.12)	<0.001	3.00 (1.21 to 7.47)	0.018
≧P_{75}	6.29 (4.09 to 9.69)	<0.001	4.53 (1.74 to 11.79)	0.002

As for the adjusted OR, adjustments were made for age, marital status, education status, occupation, PCFMI, smoking, drinking, work intensity, daily static behaviour time, whether know salt consumption will affect health, daily salt intake, physical exercise, whether know the daily salt intake standard, whether know the daily oil intake standard and whether know the risk standard of chronic diseases.
BMI, body mass index; HDC, hypertension–diabetes comorbidity; WC, waist circumference; WHtR, waist-to-height ratio.

In terms of the prevalence of HDC, we did some cross-sectional comparisons with previous studies that used the same diagnostic criteria for HDC. In our study, the prevalence of HDC among adults was lower than that of adults in India and Henan province, but higher than that of adults in Nepal.[15 25 26] This difference may be attributed to geographic variation in sociodemographics, health literacy and use of healthcare. First of all, the subjects in this study were mostly 18–39-years old, which was younger than the average age of the subjects in the above studies. In general, the older the age, the higher the risk of HDC.[27] Second, most of the research objects were non-agricultural workers, and most of them were highly educated, which was helpful for them to acquire and understand the knowledge related to disease prevention, so as to have better health literacy. Finally, Hubei province, where the research objects were located, was one of the most developed areas with medical education and medical services in China, and the transportation was convenient, which made better use of health services.

In white, black and Hispanic men of the USA, systemic obesity (BMI ≥30 kg/m^2) increased the risk of HDC by 2.2, 0.97 and 0.74 times, respectively; abdominal obesity (>102 cm in male and >88 cm in female) increased the risk of HDC by 1.63, 1.41 and 0.81 times, respectively.[9] Among males and females of England, the odds for HDC associated with generalised obesity (BMI ≥30 kg/m^2) were 2.62 and 3.02 in 2003, respectively; the odds for HDC associated with raised WC (>102 cm in male and >88 cm in female) were 1.8 and 3.6 in 2003, respectively.[10] Besides BMI, WHtR is a strong predictor of hypertension and diabetes.[28] Metabolic syndrome is a significant risk factor of morbidity and mortality in cardiovascular disease. A number of studies have shown that WHtR is better than BMI and WC in predicting metabolic syndrome.[29–31] One of the major findings of this study is that high BMI and WHtR can increase the probability of HDC, and the association between HDC and BMI is stronger than that between HDC and WHtR. This may be because BMI is more closely related to IR. IR is considered to be one of the major stages before the development of hypertension and diabetes.[7] Research conducted by Khalid *et al* showed that BMI is the best parameter to predict IR in Jordanians followed by WHtR and WC.[32] Our study did not find that WC might increase the risk of HDC. We speculated that our result varied possibly because WHtR is better than WC for evaluating abdominal obesity,[33] and the normal range of WC in men and women is different in studies in China and other countries.[18,34 35] In addition, the ethnic difference between China and other countries may also be an important factor that cannot be ignored. A previous study has indicated that race affects the association of obesity with insulin sensitivity.[36]

Gender stratification analysis revealed that high BMI and WHtR were risk factors of HDC in both males and females, and the correlation between HDC and BMI was stronger than that between HDC and WHtR. These findings were consistent with the conclusion of whole-population analysis. The probability of HDC increased only when WHtR≥P_{75} in males, but the probability of HDC increased when WHtR≥P_{25} in females. Both prospective cohort and cross-sectional studies in China have shown that the younger the age, the stronger the predictive power and association of WHtR for cardiovascular metabolic risk in women.[37 38] In our study, the total number of females was higher than that of males, and more females were found in the proportion of young adults. This variation might explain the difference in the correlation between WHtR and HDC in males and females.

Limitations

This study is a starting point to draw the public's attention to HDC among adults in Central China. Our findings will provide baseline information that may be useful to local, regional and even national governments in their attempt to prevent and control HDC more scientifically and effectively. However, we acknowledge that this study has several limitations. First, the data collection of some indicators in this study might be inaccurate because a self-reported approach was used to collect data. Recall bias may have affected survey responses. Information bias may lead to the misclassification of participants and overestimation or underestimation of HDC prevalence. Further research is required to determine what effect this might have for residents use surveys like this. Second, the cross-sectional design did not allow us to draw clear causation. Therefore, further cohort studies are needed. Third, this study was conducted in Hubei province of Central China. Due to the heterogeneity of economic level and cultural background, application of these findings to other areas and other population groups should be done with caution. Recruitment from multiple provinces should be considered in future studies. Fourth, sampling weights were not calculated, which may cause the HDC prevalence of the sample to be inconsistent with the population. Future studies need to adopt appropriate methods to obtain unbiased estimated prevalence as much as possible.

CONCLUSION

High BMI and WHtR are independent associated factors of HDC among adults in Central China. By comparison, BMI is more closely related to HDC than WHtR. The relationship between BMI, WHtR and HDC varies in males and females. Therefore, reasonable control of BMI and WHtR may be an effective measure to prevent HDC among adults. Females should focus on maintaining an optimal WHtR as soon as possible.

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