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Dose-response relationship between body mass index and hypertension: A cross-sectional study from Eastern China

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A R T I C L E I N F O

Keywords:
Hypertension
Body mass index
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Dose-response

A B S T R A C T

Background: A high body mass index (BMI) increases the risk of hypertension. However, little is known about the dose-dependent association between BMI and hypertension. Therefore, this study investigated the prevalence of hypertension in 7568 subjects from the Jiangsu Province, Eastern China, and analyzed the dose–response relationship between BMI and hypertension risk.
Methods: The eligible subjects completed a structured questionnaire and clinical biochemical indicators were measured according to standardized protocols. Multivariate logistic regression models were used to evaluate the association between BMI and hypertension. Restricted cubic spline (RCS) analysis was used to analyze the dose–response relationship between BMI and hypertension risk. Moreover, sensitivity analysis was performed to verify the robustness of our findings.
Results: The prevalence of hypertension was 35.3 % in the total population. BMI was significantly associated with systolic and diastolic blood pressure. The fully-adjusted odds ratio (OR) with 95 % confidence interval (CI) for hypertension was 1.17 (1.15, 1.19) for every 1 kg/m^2 increase in BMI. Furthermore, the OR (95 % CI) for hypertension in the highest BMI group (Obesity) was 4.14 (3.45, 4.96) after adjusting for covariates compared with the normal group. Multivariable adjusted RCS analysis showed a positive and linear dose–response relationship between BMI and hypertension risk both in male and female populations (all P for non-linearity > 0.05).
Conclusion: Our study demonstrated a positive and linear dose–response relationship between BMI and the risk of hypertension. The results of this study provide evidence for BMI-related clinical interventions to reduce the risk of hypertension.

1. Introduction

Hypertension is a chronic disease caused by factors such as high sodium intake, low potassium intake, obesity, alcohol consumption, physical inactivity, unhealthy diet. It is a significant risk factor for the development of cardiovascular diseases and stroke. Therefore, hypertension has emerged as a significant public health burden globally and contributed to 10.8 million deaths in 2019 (Poulter et al., 2015; GBD 2019 Risk Factors Collaborators, 2020). The prevalence of hypertension was 34 % among men and 32 % among women worldwide (Nguyen and Chow, 2021). Moreover, the burden of hypertension is higher in the low-income and middle-income countries (Nguyen and Chow, 2021). It has been reported that the prevalence of hypertension among Chinese adults aged between 35 to 74 years is 32.5 % and the overall control rate was less than 5.0 % (Wang et al., 2018; Lewington et al., 2016). A recent epidemiological survey in China also showed that the number of hypertensive patients increased with age (Zhang et al., 2021).

It has been established that obesity is an independent risk factor for hypertension (Rahmouni, 2014; Powell-Wiley et al., 2021; Nurdiantami et al., 2018; DeMarco et al., 2014). The combination of obesity and hypertension increases the risk of cardiovascular disease and the development of refractory arterial hypertension, both of which are associated with high morbidity and mortality (DeMarco et al., 2014). The global prevalence of obesity has dramatically increased in the recent

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decades, with rates increasing from 3 % in 1975 to 11 % in 2016 among men and from 6 % to 15 % among women during the same time frame (Jaacks et al., 2019). The body mass index (BMI) is one of the most commonly used indicators for determining the risk of developing obesity and a measure to estimate general obesity (Bays et al., 2007; Oliveros et al., 2014; Adab et al., 2018). Several studies have shown a positive association between higher BMI and increased risk of hypertension (Foti et al., 2022; Chen et al., 2018; Linderman et al., 2018). A prospective study reported that the probability of hypertension was 20 % higher for every 1 kg/m^2 increase in BMI among individuals under the age of 60 (Zhang et al., 2017). Furthermore, a population study of Chinese adults demonstrated that BMI was a more accurate predictor of blood pressure in women (Fu et al., 2018). However, BMI is generally divided into two or more groups in most studies as a continuous variable and may contribute to loss of information and poor prediction (Gauthier et al., 2020). Moreover, obesity is a progressive disease. Evaluation of obesity based on BMI categories alone may not be accurate. Therefore, there is a need to clarify the association between BMI and hypertension, especially regarding the effects of sustained changes in BMI on hypertension. Few studies have quantified the dose–response relationship between successive BMI levels and the risk of hypertension by using restricted cubic spline (RCS). Besides, to the best of our knowledge, the association between BMI levels and hypertension has not been reported for any population in Eastern China.

A previous study conducted in Jiangsu Province, China, reported that the standardized prevalence of hypertension was 48.1 %, which was higher than the national average of 37.2 % (Su et al., 2019). Additionally, another study found that hypertension and excessive sodium intake in adults were prevalent in Jiangsu Province (Yongqing et al., 2016). Therefore, this study investigated the prevalence of hypertension and explored dose–response association between BMI and hypertension risk based on a representative population from Eastern China.

2. Methods and materials

2.1. Study design and population

This multi-center cross-sectional study was conducted in the Jiangsu Province, China between March 2016 and June 2016. A multistage stratified sampling method was used to select participants aged between 18 to 65 years who resided in the Jiangsu Province for more than six months. The procedures for this cross-sectional study were performed as described previously (Chen et al., 2019). The exclusion criteria were as follows: (Poulter et al., 2015) subjects who are pregnant; (GBD 2019 Risk Factors Collaborators, 2020) subjects with severe mental disorders; (Nguyen and Chow, 2021) subjects diagnosed with cancer or malignant tumors; and (Wang et al., 2018) subjects without BMI and blood pressure measurements. Initially, we enrolled 7689 subjects. After screening the data and applying the exclusion criteria, we finally included 7568 subjects in the analysis. This study was conducted in accordance with the Declaration of Helsinki and informed consent was obtained from all the participants prior to the survey. This research protocol was approved by the Ethics Review Board of Jiangsu Provincial Center for Disease Control and Prevention (Approval No. JSJK2016-B003-03).

2.2. Exposure and outcome parameters

Trained professionals measured height, weight, and blood pressure twice using standardized equipment. A height-weight meter was used to measure the net height and weight of the participants without footwear while wearing lightweight garments. BMI was calculated as weight/height (kg/m^2), and was categorized into the following three groups: normal (BMI $<$ 25.0 kg/m^2), overweight (25.0 $\leq$ BMI $<$ 30.0 kg/m^2) and obesity (BMI$\geq$30.0 kg/m^2). A professional observer measured systolic blood pressure (SBP) and diastolic blood pressure (DBP) for all the subjects after five minutes of rest in a sitting position using an electronic sphygmograph. Hypertension was defined as SBP $\geq$140 mmHg and/or DBP $\geq$90 mmHg, or a self-reported history of hypertension (Chobanian et al., 2003).

2.3. Assessment of covariates

The following demographic variables were collected using a structured questionnaire: age, gender, education level, marital status, physical activity level, smoking habits, and alcohol consumption. The subjects were divided by age into the following four categories: 18–34 years; 35–44 years; 45–54 years; and 55–65 years. The level of education was grouped into the following three categories based on the years of schooling: 0–6 years; 7–12 years; and $\geq$12 years. Marital status was classified into the following two categories: married and other (unmarried, divorced, or widowed). Physical activity level was classified into the following three categories based on the International Physical Activity Short Form (IPAQ-SF): low; moderate; and high (Craig et al., 2003). Smoking habits and alcohol consumption were classified into the following two groups: never or yes. Current smokers were defined as those who smoked 1 or more cigarettes per week. Drinking alcohol at least once a week in the past 1 year was considered to be consuming alcohol. The blood glucose and blood lipid measurements were performed as previously described (Chen et al., 2019). Diabetes was defined as fasting plasma glucose level $\geq$7.0 mmol/L or 2-h plasma glucose level $\geq$11.1 mmol/L, or glycosylated hemoglobin level $\geq$6.5 % according to the latest diagnostic criteria from the American Diabetes Association (American Diabetes Association Professional Practice Committee, 2022). Dyslipidemia was defined as total cholesterol $\geq$6.22 mmol/L, and/or triglycerides $\geq$2.26 mmol/L, and/or low-density lipoprotein cholesterol $\geq$4.14 mmol/L, and/or high-density lipoprotein cholesterol $<$1.04 mmol/L, or self-reported history of dyslipidemia (Zhu et al., 2022).

2.4. Statistical analysis

The normality of data was analyzed using the Kolmogorov-Smirnov test. The continuous variables were represented as mean $\pm$ standard deviation for normally distributed data and median (interquartile range) for non-normally distributed or skewed data. Categorical variables were reported as numbers and percentages. One-way ANOVA test (for normally distributed data), Kruskal-Wallis test (for skewed distribution data), or Chi-square test (for categorical variables) were used to analyze the statistically significant differences between groups. The distribution of BMI in the study population with and without hypertension was visualized using the Gaussian kernel density plot analysis. The association of BMI with SBP and DBP was estimated using generalized additive models and the Spearman correlation analysis. Multivariate logistic regression models were used to evaluate the relationship of BMI with hypertension. The odds ratios (ORs) with 95 % confidence intervals (CIs) were calculated using the lowest quartile as reference. Model 1 was unadjusted, model 2 was adjusted for sex and age, and model 3 was further adjusted for education level, marital status, physical activity level, smoking, alcohol drinking, diabetes, and dyslipidemia. The median of each exposure category was modeled as a continuous variable in every logistic regression model to test for linearity. The potential linear or non-linear relationships between BMI levels and the risk of hypertension were analyzed on a continuous scale with the RCS curves based on the fully adjusted logistic regression models. The four knots were located at the 5th, 35th, 65th, and 95th percentiles. Additional analyses of the data were also conducted considering the sampling scheme. Furthermore, given that isolated systolic hypertension (SBP $\geq$140 and DBP $<$90 mmHg) is relatively common among Chinese than other European populations, we performed the same logistic regression and RCS analysis to investigate the relationship between BMI and isolated systolic hypertension. The robustness of the model results was estimated by performing a sensitivity analysis with altered cut-off points for hypertension (SBP ≥135 mmHg and/or DBP ≥85 mmHg) (Unger et al., 2020). All the statistical analyses were performed using the Statistical Package for Social Sciences software for Windows, version 26.0 (SPSS, Chicago, IL) and R software version 4.1.1 (64-bit). Two-tailed $P < 0.05$ was considered statistically significant.

3. Results

3.1. Characteristics of the study population

The basic characteristics of the study participants according to the presence or absence of hypertension are shown in Table 1. This study included 3322 (43.9 %) males and 4246 (56.1 %) females. The prevalence of hypertension was 35.3 % in the total population, including 40.8 % among men and 31.0 % among women. The median age of the study participants was 46.00 (34.00, 53.00) years. The median BMI was 24.82 (22.41, 27.50) kg/m^2. The median values of SBP and DBP were 126.00 (115.00, 140.00) mmHg and 79.00 (71.00, 87.00) mmHg, respectively.

Table 1
Basic characteristics of the study population among Eastern China adults in 2016.

Variables	Hypertension (n = 2671)	Non-hypertension (n = 4897)	*P*-value
Age, n (%)			<0.001
18–34 years old	248 (9.3)	1738 (35.5)	
35–44 years old	422 (15.8)	1162 (23.7)	
45–54 years old	1115 (41.7)	1397 (28.5)	
55–65 years old	886 (33.2)	600 (12.3)	
Gender, n (%)			<0.001
Male	1355 (50.7)	1967 (40.2)	
Female	1316 (49.3)	2930 (59.8)	
Education level, n (%)			<0.001
0–6 years	1004 (37.6)	1073 (21.9)	
7–12 years	1557 (58.3)	3218 (65.7)	
≥12 years	110 (4.1)	606 (12.4)	
Marital status, n (%)			<0.001
Married	2535 (94.9)	4435 (90.6)	
Other	136 (5.1)	462 (9.4)	
Physical activity, n (%)			<0.001
Low	1086 (40.7)	2356 (48.1)	
Moderate	888 (33.2)	1487 (30.4)	
High	697 (26.1)	1054 (21.5)	
Smoking, n (%)			<0.001
Never	1864 (69.8)	3761 (76.8)	
Yes	807 (30.2)	1136 (23.2)	
Alcohol drinking, n (%)			<0.001
Never	1729 (64.7)	3756 (76.7)	
Yes	942 (35.3)	1141 (23.3)	
BMI (kg/m^2)	26.33 (24.09, 28.76)	23.93 (21.60, 26.45)	<0.001
HbA1c (%)	5.7 (5.4, 6.0)	5.5 (5.3,5.8)	<0.001
FPG (mmol/L)	5.50 (5.11, 6.01)	5.20 (4.90, 5.57)	<0.001
2-h PG (mmol/L)	6.51 (5.54, 8.06)	5.78 (5.01, 6.76)	<0.001
SBP (mmHg)	145.00 (138.00, 155.00)	119.00 (110.00, 127.00)	<0.001
DBP (mmHg)	90.00 (82.00, 95.00)	74.00 (68.00, 80.00)	<0.001
TC (mmol/L)	4.77 (4.23, 5.33)	4.46 (3.92, 5.08)	<0.001
TG (mmol/L)	1.46 (1.00, 2.18)	1.09 (0.79, 1.64)	<0.001
HDL-C (mmol/L)	1.32 (1.12, 1.53)	1.35 (1.15, 1.56)	<0.001
LDL-C (mmol/L)	2.68 (2.24, 3.17)	2.44 (2.07, 2.93)	<0.001
Diabetes, n (%)			<0.001
Yes	383 (14.3)	215 (4.4)	
No	2288 (85.7)	4682 (95.6)	
Dyslipidemia, n (%)			<0.001
Yes	1004 (37.6)	1191 (24.3)	
No	1667 (62.4)	3706 (75.7)	

BMI, body mass index; HbA1c, glycated hemoglobin; FBG, fasting plasma glucose; 2-h PG, 2-h plasma glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

The subjects with hypertension showed significantly higher BMI and other biochemical indicators compared with those without hypertension (all $P < 0.001$). Besides, compared to residents without hypertension, individuals with hypertension exhibited a higher proportion of men and had greater prevalence of smoking, alcohol drinking, diabetes and dyslipidemia (all $P < 0.001$). The distribution of BMI stratified by gender in the hypertension and non-hypertension populations is presented in Fig. 1.

3.2. The correlation between BMI, SBP, and DBP

The fitted curves for assessing the relationship of BMI with SBP and DBP based on the generalized additive model are shown in the Fig. 2A-B, and the adjusted fitted curves are presented in the Supplementary Material 1 (Supplementary Fig. 1). Both SBP and DBP showed an upward trend with increasing BMI. Spearman correlation analysis results demonstrated that the correlation coefficients for the relationship of BMI with SBP and DBP were 0.35 and 0.32, respectively (all $P < 0.001$). The correlation heat map for the association of BMI with SBP and DBP is shown in Fig. 2C.

3.3. The association between BMI and hypertension

Table 2 shows the results for the logistic regression analysis to determine the association between BMI and hypertension. When analyzed as continuous variables, BMI was significantly associated with hypertension in all the three models with ORs of 1.19 (1.17, 1.21), 1.19 (1.17, 1.20) and 1.17 (1.15, 1.19), respectively. Furthermore, when analyzed as categorical variables, the risk of hypertension increased proportionately from normal group to obesity group in all the models (all *P* for trend <0.001). In the fully adjusted model, participants in the obesity group demonstrated a 4.14-fold increased risk of hypertension when compared with those in the normal group as reference. The logistic regression results with consideration of the sampling scheme are displayed in the Supplementary Material 2 (Supplementary Table 1). In addition, BMI was significantly associated with isolated systolic hypertension in all the three models, and the results are shown in Supplementary Material 1 (Supplementary Table 2).

3.4. Dose-response relationship between BMI and hypertension

RCS regression models with four knots were used to investigate the relationship between BMI and risk of hypertension. RCS analysis results demonstrated a linear dose–response association between BMI and hypertension in both males and females after adjusting for the potential confounders (all *P* for non-linearity > 0.05). RCS analysis results also showed that the risk of hypertension was significantly higher when the BMI was >25.17 kg/m^2 in men and >24.50 kg/m^2 in women (Fig. 3).

In the males, compared with a BMI of 25.17 kg/m^2 (OR = 1) as reference, the ORs (95 % CIs) for the four BMI knots at 19.37 kg/m^2, 23.81 kg/m^2, 26.62 kg/m^2, and 31.87 kg/m^2 were 0.41 (0.30, 0.56), 0.76 (0.70, 0.82), 1.34 (1.23, 1.47), and 2.57 (2.06, 3.20), respectively (Fig. 3A). In the females, compared with a BMI of 24.50 kg/m^2 (OR = 1) as reference, the ORs (95 % CIs) for the four BMI knots at 19.15 kg/m^2, 23.09 kg/m^2, 26.00 kg/m^2, and 31.60 kg/m^2 were 0.40 (0.29, 0.56), 0.76 (0.71, 0.82), 1.32 (1.21, 1.45) and 2.75 (2.25, 3.37), respectively (Fig. 3B). Furthermore, we investigated the dose–response relationship in different age groups. The RCS results showed a linear association between BMI and the risk of hypertension across all the age groups (all *P* values for non-linearity > 0.05) (Fig. 4). The RCS results considering sampling weights are shown in the Supplementary material 2, and we found that the results obtained without the consideration of sampling weights were similar to the analysis results with sampling scheme. We also found that there was a liner dose–response relationship between BMI and isolated systolic hypertension regardless of gender or age (all *P* for non-linearity > 0.05), and the results are shown in the

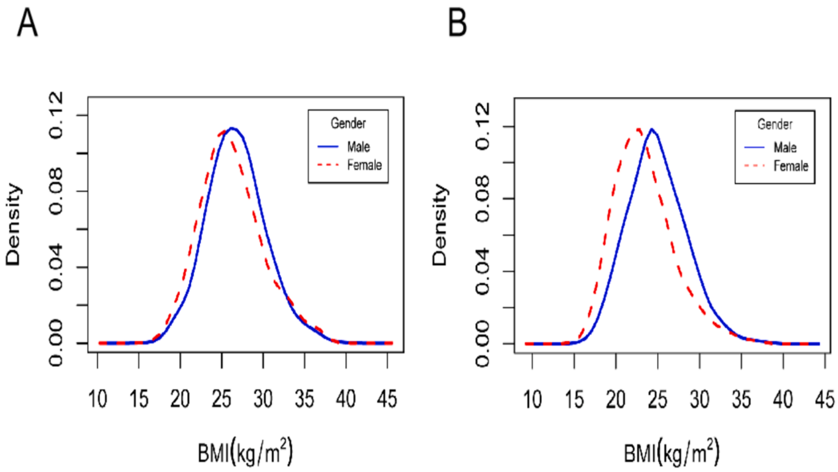

Fig. 1. Distribution of BMI in people with (A) and without (B) hypertension among Eastern China adults in 2016. BMI, body mass index.

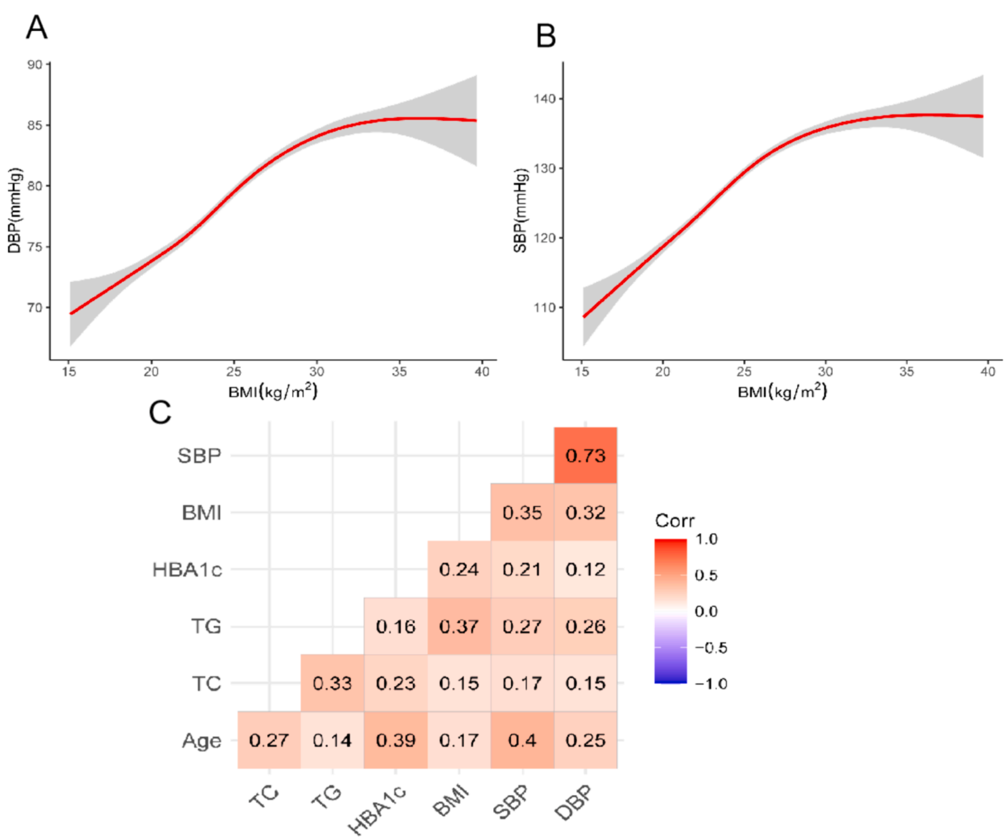

Fig. 2. The fitted curves on the relationship of BMI with DBP (A), SBP (B) among Eastern China adults in 2016. The correlation heat map (c). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure. TC, total cholesterol; TG, triglycerides; HbA1c, glycated hemoglobin.

Supplementary material 1 (Supplementary Figs. 2-3).

3.5. Sensitivity analysis

Next, we re-analyzed the association between BMI and hypertension by using different cut-off points for hypertension (SBP ≥135 mmHg and/or DBP ≥85 mmHg). The results of the logistic regression models and RCS model analyses were similar to those obtained using a hypertension cut-off value of 140/90 mmHg (Supplementary material 3).

4. Discussion

In this cross-sectional study of a population from the Jiangsu Province in Eastern China, the prevalence of hypertension was 35.3 %. Furthermore, BMI was significantly associated with the risk of hypertension after adjusting for potential confounding factors. Moreover, based on the dose–response relationship analysis, we observed a linear dose–response relationship between BMI and the risk of hypertension, regardless of gender or age.

According to the monitoring data from the “National Chronic Disease and Risk Factor Surveillance” of China in 2018, the prevalence of hypertension among adults was 27.5 % (Zhang et al., 2021). This was

Table 2
Logistic regression analyses of the association between BMI and hypertension among Eastern China adults in 2016.

	Model1 OR (95 %CI)	*P*	Model2 OR (95 %CI)	*P*	Model3 OR (95 %CI)	*P*
Total						
BMI (per 1 kg/m^2)	1.19 (1.17, 1.21)	<0.001	1.19 (1.17, 1.20)	<0.001	1.17 (1.15, 1.19)	<0.001
Categories						
Normal	Reference		Reference		Reference	
Overweight	2.82 (2.54, 3.13)	<0.001	2.52 (2.25, 2.81)	<0.001	2.31 (2.07, 2.60)	<0.001
Obesity	4.31 (3.67, 5.06)	<0.001	4.82 (4.04, 5.75)	<0.001	4.14 (3.45, 4.96)	<0.001
P for trend	<0.001		<0.001		<0.001	

Note: Model 1: unadjusted. Model 2: adjusted for age and sex. Model 3: adjusted for age, sex, education level, marital status, physical activity, smoking, alcohol drinking, diabetes and dyslipidemia.

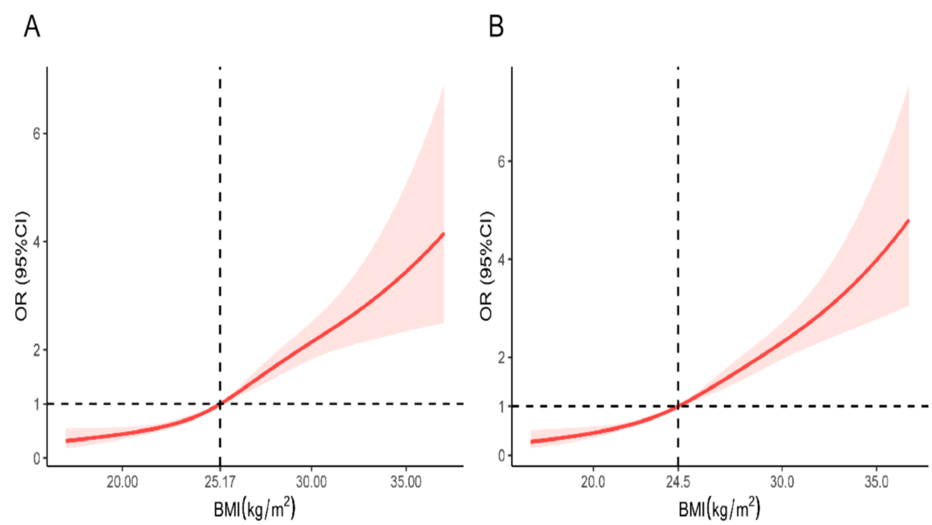

Fig. 3. Dose-response relationship between hypertension with BMI. (A) Males, (B) females among Eastern China adults in 2016. The associations were adjusted for age, education level, marital status, physical activity, smoking, alcohol drinking, diabetes and dyslipidemia. The black vertical dashed lines represent the corresponding BMI values when OR is 1. OR, odds ratio; CI, confidence intervals; BMI, body mass index.

lower than the rate of 35.3 % in this study. The prevalence of hypertension in our study was also slightly higher than the 33.0 % reported by another study from the Jiangsu province (Yongqing et al., 2016). These findings indicate that hypertension is a significant public health issue in China.

The present study also demonstrated a positive relationship between BMI and hypertension. Although previous studies have reported contradictory findings regarding the predictive value of BMI in assessing the risk of hypertension (Zhou et al., 2009; Chen et al., 2015; Shrestha et al., 2021; Ashwell et al., 2012), BMI remains a convenient and practical anthropometric measure of the overall body weight (Bays et al., 2007; Oliveros et al., 2014; Adab et al., 2018). The association between BMI and hypertension has been explored in multiple ethnic populations. A cross-sectional study of 821,040 subjects from three South Asian countries reported that the positive relationship between BMI and hypertension was consistent across subgroups of sex, age, education level, urbanization, and household economic status (Hossain et al., 2019). Shihab et al. (2012) performed a prospective cohort study of 1132 Caucasian males from the United States and demonstrated that 508 study subjects developed hypertension during follow-up. Furthermore, males with normal weight at the age of 25 but overweight or obese by the age of 45 showed a higher risk of hypertension compared to those who maintained normal weight when they were 25 as well as 45 years old (Shihab et al., 2012). Our study also confirmed the relationship between the levels of BMI and hypertension. We observed that for every 1 kg/m^2 increase in BMI, the multivariable adjusted OR was 1.17 [1.15, 1.19], which confirmed that BMI is a significant risk factor of hypertension. More importantly, the interactions between BMI and hypertension may influence disease severity. For example, Yahya and colleagues concluded that there is a synergistic effect between BMI and hypertension on the risk of type 2 diabetes mellitus after controlling for confounding factors (Pasdar et al., 2024).

However, BMI is often divided into three or more groups in most relevant studies and may lead to loss of information and/or poor prediction (Gauthier et al., 2020). Besides, the use of categorical measures of BMI such as low weight, normal weight, overweight, and obesity in the traditional logistic regression models does not reflect the dose–response relationship for continuous changes in the BMI and the risk of hypertension. RCS model allows analysis of consecutive changes in the exposure risk without abrupt transitions from one group to another (Desquilbet and Mariotti, 2010) and provides a visual representation of the complex linear or non-linear relationships between quantitative data and the outcome. In the present study, we demonstrated a linear dose–response relationship between BMI and the risk of hypertension. Our findings are comparable to the results from previous studies (Bombelli et al., 2011; Jayedi et al., 2018; Li et al., 2022). In a cohort study (Li et al., 2022) of 2812 men with a mean age of 38.7 years and without hypertension at baseline, RCS Cox regression models demonstrated a consistent positive linear association between BMI and the hazard ratio for hypertension. However, another cross-sectional study from China among the elderly (Zhang et al., 2021) showed that an increase in BMI was associated with a non-linear increase in the risk of hypertension after adjusting for the confounding factors. Moreover, Wang and colleagues (Wang et al., 2022) reported a non-linear dose–response

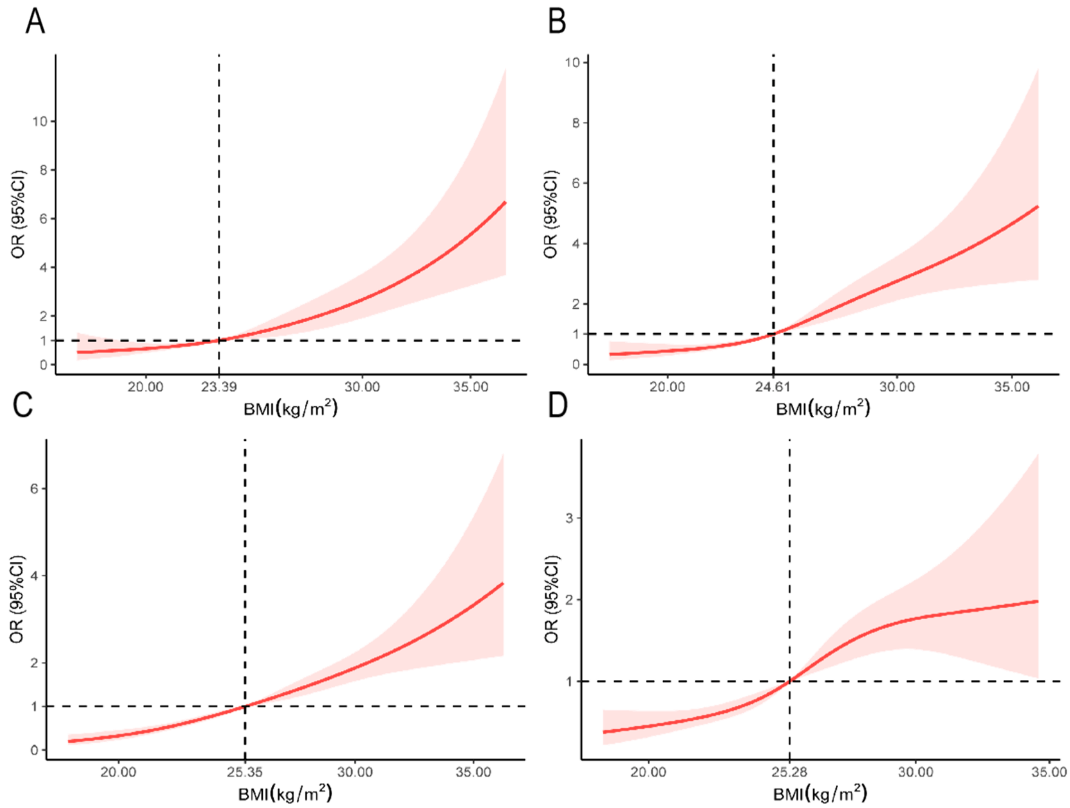

Fig. 4. Dose-response relationship between hypertension and BMI, (A) 18–34 years old; (B) 35–44 years old; (C) 45–54 years old; (D) 55–65 years old among Eastern China adults in 2016. The associations were adjusted for sex, education level, marital status, physical activity, smoking, alcohol drinking, diabetes and dyslipidemia. The black vertical dashed lines represent the corresponding BMI values when OR is 1. OR, odds ratio; CI, confidence intervals; BMI, body mass index.

relationship between the BMI and hypertension in children and adolescents. A possible reason for this discrepancy is that the age composition of the study subjects was different between these studies (Yu et al., 2018). Nevertheless, the dose–response curves demonstrated a positive association between continuous BMI levels and the risk of hypertension.

Although the exact causative mechanisms underlying the relationship between obesity and hypertension remain unclear, epidemiological studies have consistently demonstrated a positive correlation between these two variables (Rahmouni, 2014; Mills et al., 2020). Obesity contributes to the development of hypertension through a complex interplay between dietary, genetic, epigenetic, and environmental factors. The pathophysiological mechanisms for obesity-induced hypertension cause increased intravascular volume, cardiac output, and renal proximal tubular sodium absorption, which results in the impairment of vasoconstriction (DeMarco et al., 2014). Moreover, adipocyte dysfunction in obese patients leads to insulin resistance and dysregulation of the renin-angiotensin-aldosterone system and further contributing to the development of hypertension (DeMarco et al., 2014).

Several limitations of this study should be mentioned. Firstly, this was a cross-sectional study, and did not evaluate the causal relationship between BMI and hypertension. Secondly, we adjusted for potential confounding factors in the regression models, but it is plausible that other confounding factors may not have been considered. For example, the antihypertension medication and treatment information for diabetes and dyslipidemia were not available in this study. Thirdly, it should be noted that the sample population of this study was limited to individuals aged 18–65 residing in Eastern China. Therefore, caution must be exercised when generalizing these findings to other ethnic groups. Further studies in diverse populations are required to validate our findings regarding the relationship between BMI and hypertension.

5. Conclusions

Our data demonstrated that hypertension was highly prevalent in the Eastern Chinese population. We established a linear dose–response relationship between BMI and the risk of hypertension. Our findings emphasize the significance of maintaining BMI within the normal range, preferably at a lower level, to prevent the development of hypertension.

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CRediT authorship contribution statement

Lei Yuan: Writing – original draft, Visualization, Software, Formal analysis. **Chen Qu:** Writing – review & editing, Supervision, Investigation, Data curation. **Jinhang Zhao:** Writing – original draft, Visualization, Software. **Lijun Lu:** Software, Formal analysis. **Jiaping Chen:** Validation, Resources, Methodology. **Yan Xu:** Investigation, Data curation. **Xiaoning Li:** Investigation, Data curation. **Tao Mao:** Investigation, Data curation. **Guoping Yang:** Investigation, Data curation. **Shiqi Zhen:** Writing – review & editing, Supervision, Investigation, Data curation, Conceptualization. **Sijun Liu:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Ethics statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Review Board of Jiangsu Provincial Center for Disease Control and Prevention (No. JSJK2016-B003–03). Informed consent was obtained from all subjects before the start of the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102852.

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