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Anthropometric Indices Predict the Development of Hypertension in Normotensive and Pre-Hypertensive Middle-Aged Women in Tianjin, China: A Prospective Cohort Study

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Background: The aims of this study were to investigate the relationship between optimal anthropometric indices and their cut-off values and the incidence of hypertension in a cohort of middle-aged women in China.

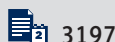
Material/Methods: A cohort of 812 women, aged between 40–70 years were recruited between May 2011 and June 2013. An ideal baseline blood pressure was defined as <120/80 mmHg; pre-hypertension was 120–139/80–89 mmHg; hypertension was $\geq 140/\geq 90$ mmHg. Anthropometric measurements included waist circumference (WC), body mass index (BMI), waist-hip ratio (WHR), and waist-height ratio (WHtR). The cohort was divided into an ideal blood pressure group (Group 1) and a pre-hypertensive group (Group 2). Two-year follow-up blood pressure measurements were performed. Receiver-operating characteristic (ROC) curve analysis determined the optimal anthropometric indices and cut-off values for developing hypertension.

Results: At two-year follow-up, hypertension developed in 9.0% (n=31) in Group 1 and 32.3% (n=121) in Group 2. Logistic regression analysis showed that in both groups, women in the highest quartile for WC, BMI, WHR, and WHtR had a significantly increased risk of developing hypertension compared with the lowest quartile ($P < 0.05$). ROC curve area under the curve (AUC) for these anthropometric indices were greater in Group 1, and for WC in Groups 1 and 2, with the optimal cut-off values greater in Group 1.

Conclusions: In a cohort of middle-aged women in China, anthropometric indices of obesity were predictive of the development of hypertension during a two-year follow-up period.

MeSH Keywords: **Hypertension • Metabolism • Obesity • Prehypertension**

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Background

Worldwide, including in China, the increasing prevalence of hypertension is becoming a significant public health problem, resulting in high morbidity and mortality [1]. Therefore, primary prevention of hypertension is important. The concept of pre-hypertension was first proposed in 2003, in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (the JNC 7 report) [2]. Although the 2017 American College of Cardiology and American Heart Association (ACC/AHA) guidelines on the prevention, diagnosis, and management of hypertension in adults has proposed new definition of high blood pressure, there is still some controversy regarding the applicability of the recent ACC/AHA clinical criteria for the Chinese population [3]. Of relevance to the present study, mildly elevated blood pressure or Stage 1 hypertension in the 2017 ACC/AHA guidelines, which recommend non-pharmacological therapy, was chosen as a group in the present study, termed the 'pre-hypertensive group' (Group 2) [3].

Among the independent risk factors for progression from normal or ideal blood pressure to hypertension, obesity is an important factor that is increasing globally, especially in China [4–9]. Anthropometric indices of obesity are recognized to be associated the development of hypertension, and various anthropometric measurements that reflect overweight and obesity include waist circumference (WC), body mass index (BMI), waist-hip ratio (WHR), and waist-height ratio (WHtR), although which of these indices best predicts the development of hypertension remains controversial [10–13]. Recent studies have shown that anthropometric indices of increased weight and obesity are associated with the incidence of hypertension in pre-hypertensive populations [14–16]. However, few studies have focused on whether these indices have different effects in pre-hypertensive populations, compared with those an ideal or normal blood pressure.

The aims of this prospective cohort study were to investigate the relationship between anthropometric indices and their optimal cut-off values and the incidence of hypertension in a cohort of middle-aged (between 40–70 years) Chinese women. The anthropometric indices chosen included WC, BMI, WHR, and WHtR and the use of receiver-operating characteristic (ROC) curve analysis to demonstrate the optimal cut-off value and reveal the best indices for predicting the development of hypertension during a two-year follow-up period. To the best of our knowledge, this was the first prospective cohort study to use ROC curve analysis to determine optimal cut-off values of anthropometric indices in middle-aged pre-hypertensive Chinese women.

Material and Methods

Study cohort and groups

This study was a population-based prospective cohort study that recruited 812 urban female residents in Tianjin, China, aged between 40–70 years who were not hypertensive. Cluster stratification sampling was used to recruit subjects in six districts of Tianjin between May 2011 and June 2013. The study exclusion criteria included high blood pressure (systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg), women who were being treated with anti-hypertensive drugs, who were in renal failure, or who had severe hepatic insufficiency, cancer, cerebrovascular disease, tuberculosis, autoimmune disease, systemic infections, any woman who was unable to cooperate in the study, or any woman with heart failure according to the New York Heart Association (NYHA) Class III–IV.

The study cohort was divided into two groups. Group 1 had a baseline ideal, or normal, blood pressure. Group 2, or the 'pre-hypertensive group' were equivalent to the mildly elevated blood pressure or Stage 1 hypertension classification used in the 2017 American College of Cardiology and American Heart Association (ACC/AHA) guidelines, which recommend non-pharmacological therapy in these cases [3].

After receiving complete information about the aims and methods of the study, all participants gave written informed consent for the examinations and follow-up. The demographic and medical history of the women in the study cohort were obtained using a structured questionnaire, which included sex, age, smoking history, and family history of hypertension. Between May 2013 and June 2015, the data of all the subjects were measured again, excluding those who were lost during the two-year follow-up. The final sample size of the study cohort comprised 719 women for analysis.

Blood pressure measurement

The blood pressure measurements were taken on the right arm after a 15-minute rest and between the hours of 8 a.m. to 9 a.m., using a calibrated mercury sphygmomanometer by trained health workers. The appearance of Korotkoff sounds (phase 1) was the criterion for measurement of the systolic blood pressure (SBP), and the disappearance of the Korotkoff sounds (phase 5) was the criterion for the measurement of diastolic blood pressure (DBP). Blood pressure measurements were taken in triplicate at two-minute intervals, and the average value was used to record the SBP and DBP. None of the subjects had tea, coffee, alcohol, or smoked cigarettes during the 30 minutes before the blood pressure measurements.

An ideal, or normal, blood pressure was defined as a baseline SBP <120 mmHg and DBP <80 mmHg; pre-hypertension was defined as a baseline SBP of 120–139 mmHg, or a DBP of 80–89 mmHg, or both; hypertension at follow-up was defined as a SBP \geq 140 mmHg or a DBP \geq 90 mmHg, or both, or as hypertension diagnosed at other hospitals during the two-year follow-up [2].

Anthropometric indices

Trained health workers took anthropometric measurements. Height was measured to the nearest cm without the woman wearing shoes. Weight was measured to the nearest kg without heavy clothes. Each woman's waist circumference (WC) was defined as the midpoint between the lower rib and upper margin of the iliac crest and measured using a tape measure with an insertion buckle at one end. Hip circumference (HC) was measured at the level of the maximal gluteal protrusion. The WC and HC were measured to the nearest cm. The body mass index (BMI) was calculated by dividing weight in kg by the height in meters² (kg/m²). The waist-hip ratio (WHR) was calculated as the WC/HC. The waist-height ratio (WHtR) was calculated as the WC/height [17]. Measurements of BMI, WC, WHR, and WHtR were divided into quartiles to determine whether these indices were associated with the incidence of hypertension.

Biochemical indices

Fasting blood glucose (FBG), total cholesterol (TC), triglyceride (TG), high-density lipoprotein-cholesterol (HDL-C), low-density lipoprotein-cholesterol (LDL-C), serum creatinine (Cr), uric acid (UA), and high sensitivity C-reactive protein (hs-CRP) were measured after 12 hours of overnight fasting. Postprandial blood glucose (PBG) was measured after drinking 250 mL of water mixed with 75 g dextrose anhydrate. All the biochemical indices were measured from venous blood samples using a Roche C8000 Automated Analyzer at the Laboratory Center of the General Hospital of Tianjin Medical University. All quality control indices of the laboratory analysis met the requirements of the professional laboratories of the Tianjin Medical University General Hospital in strict accordance with laboratory protocols.

Statistical analysis

All statistical analyses were performed using SPSS version 21 (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as the mean \pm standard deviation (SD), and categorical variables were presented as percentages. A t-test was used to compare continuous variables between subjects with ideal, or normal, blood pressure and pre-hypertension subjects, and the chi-squared (χ^2) test was used for categorical data. The contribution of anthropometric indices to the development

of hypertension was evaluated using binary logistic analysis. Receiver-operating characteristic (ROC) curve analysis and the area under the curve (AUC) determined the optimal anthropometric indices and cut-off values for developing hypertension. Optimal cut-off values for the anthropometric measurements were determined using Youden's index. $P < 0.05$ was considered as statistically significant.

Results

Of the 719 women in the study cohort, 47.8% (n=344) were in Group 1, with an ideal, or normal, blood pressure, and 52.2% (n=375) were in Group 2, the pre-hypertension group. Table 1 shows the clinical and anthropometric characteristics of the study population.

At baseline, when the women were initially recruited into the study cohort, the mean age, waist circumference (WC), body mass index (BMI), waist-hip ratio (WHR), and waist-height ratio (WHtR), fasting blood glucose (FBG), postprandial blood glucose (PBG), total cholesterol (TC), triglyceride (TG), low-density lipoprotein-cholesterol (LDL-C), and uric acid (UA) were significantly greater in Group 2 compared with Group 1, while high-density lipoprotein-cholesterol (HDL-C) was significantly greater in Group 1 ($P < 0.05$). The smoking history and family history of hypertension showed no significant differences between the two groups.

During the two-year follow-up period, 9.0% (n=31) in Group 1, and 32.3% (n=121) in Group 2 developed hypertension. The incidence of hypertension in Group 2 was significantly greater compared with Group 1 ($\chi^2=58.2$; $P < 0.001$). Also, there was a significant trend of an increased incidence of hypertension with an increase in WC, BMI, WHR, and WHtR ($P < 0.05$) in both Group 1 and Group 2 (Figure 1).

Table 2 shows the association between the anthropometric indices and the incidence of hypertension. Univariate logistic regression analysis indicated that women in both groups in the highest quartile of WC, BMI, WHR, and WHtR had the greatest risk of developing hypertension compared with women in the lowest quartile. Even after adjusting for age, UA, FBG, PBG, LDL-C family history, and smoking history, these anthropometric indices remained statistically significant. However, there was no statistically significant difference in anthropometric indices between quartiles 2 and 3, compared with quartile 1.

To determine the most effective anthropometric indices in predicting the incidence of developing hypertension, analysis of the receiver-operating characteristic (ROC) curve and the area under the curve (AUC) for these anthropometric indices in relation to the incidence of hypertension were calculated (Figure 2).

Table 1. Characteristics in both groups.

Variables	Group 1 (n=344)	Group 2 (n=375)	P value
Age (years)	54.83±6.30	57.22±6.52	<0.001
Anthropometric indices			
WC (cm)	80.77±7.94	86.23±8.84	<0.001
BMI (kg/m ²)	23.23±2.82	25.20±3.37	<0.001
WHR	0.833±0.054	0.852±0.053	<0.001
WHtR	0.501±0.049	0.537±0.055	<0.001
Biochemistry test			
FBG (mmol/L)	5.23±1.43	5.57±1.43	<0.001
PBG (mmol/L)	6.68±2.80	7.50±3.50	0.001
TC (mmol/L)	5.46±1.06	5.70±1.03	0.002
TG (mmol/L)	1.46±1.21	1.78±1.23	<0.001
HDL-C (mmol/L)	1.54±0.37	1.48±0.39	0.039
LDL-C (mmol/L)	3.33±0.94	3.47±0.92	0.047
Scr (mmol/L)	58.88±8.94	59.35±8.99	0.479
UA (mmol/L)	263.16±63.07	280.93±61.11	<0.001
hs-CRP (mg/L)	2.56±3.60	2.86±6.68	0.452
Other hypertension risk factors			
Smoking (%)	15 (4.4)	11 (2.9)	>0.05
Family history (%)	180 (52.3)	212 (56.5)	>0.05
Blood pressure			
Baseline SBP (mmHg)	110.59±6.50	128.06±5.88	<0.001
Baseline DBP (mmHg)	70.51±4.92	79.06±5.49	<0.001
Follow-up SBP (mmHg)	117.28±21.71	128.53±12.52	<0.001
Follow-up DBP (mmHg)	74.57±7.63	81.36±8.14	<0.001

Group 1, ideal blood pressure group; Group 2, pre-hypertensive group. WC – waist circumference; BMI – body mass index; WHR – waist-hip ratio; WHtR – waist-height ratio; FBG – fasting blood glucose; PBG – postprandial blood glucose; TC – total cholesterol; TG – triglyceride; HDL-C – high-density lipoprotein cholesterol; LDL – low-density lipoprotein cholesterol; Scr – serum creatinine; UA – uric acid; hs-CRP – high sensitivity C-reactive protein.

As shown in Table 3, WC has the highest AUC among the four indices (WC, BMI, WHR, and WHtR) in both groups. Compared with Group 2, the AUC of all the four indices were higher in Group 1. Also, the optimal cut-off points of the anthropometric indices for predicting hypertension were calculated using Youden's index (Table 3), which showed that the cut-off points for WC, BMI, WHR, and WHtR were higher in Group 2 than in Group 1. Youden's index for WHtR appeared to be the highest in Group 1 and WC in Group 2 among the measured obesity anthropometric indices.

Discussion

In this cohort study of 812 middle-aged women in China, aged between 40–70 years, women were divided into an ideal, or normal, blood pressure group (Group 1) and a pre-hypertensive group (Group 2) on recruitment. The aims of the study were to determine whether anthropometric measurements, including waist circumference (WC), body mass index (BMI), waist-hip ratio (WHR), and waist-height ratio (WHtR) were predictive for the development of hypertension. The findings were that after two-year follow-up, the receiver-operating characteristic (ROC) curve and the area under the curve (AUC) analysis showed that WC had the highest AUC among the four

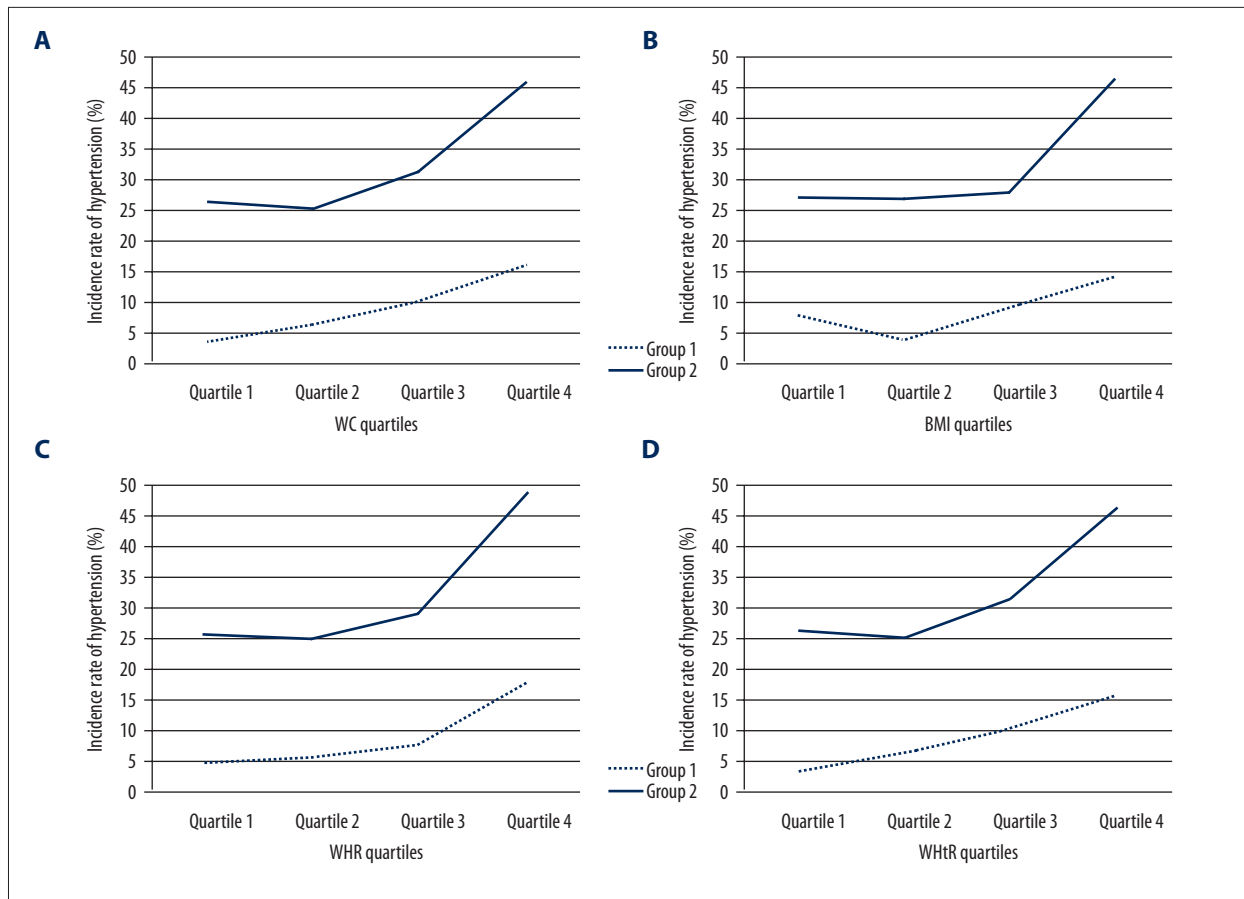


Figure 1. The relationship between anthropometric indices quartiles and incidence of hypertension during the 2-year follow-up in both groups. Group 1, ideal blood pressure group; Group 2, pre-hypertensive group. WC – waist circumference; BMI – body mass index; WHR – waist-hip ratio; WHtR – waist-height ratio.

indices (WC, BMI, WHR, and WHtR), in both groups, but compared with Group 2, the AUC of all the four indices were higher in Group 1, and the optimal cut-off points of the anthropometric indices for predicting hypertension were all higher in Group 2 than in Group 1, and that WHtR had the highest index in Group 1 and WC had the highest index Group 2. The findings of this study showed that, in a cohort of middle-aged Chinese women, anthropometric indices were different in their ability to predicting hypertension in pre-hypertensive women compared with women with an ideal, or normal, initial blood pressure. These findings may have implications for the prevention of hypertension in this population.

Obesity is a major risk factor for hypertension that can be effectively controlled through exercise and diet, and control of obesity is recognized to have an important role in primary prevention of hypertension. The mechanism of the association between obesity and hypertension might be explained by the increase in leptin in obesity, the decrease in adiponectin, and in the development of insulin resistance [18–21]. This study used some of the main anthropometric assessment methods for obesity, including WC,

BMI, WHR, and WHtR. However, there remains some controversy as to which is the best of the anthropometric and other indices for predicting the development of hypertension.

Several previously published studies have supported the finding that WC is the best predictor for the development of hypertension [12–14,22]. However, other studies have suggested that WHR or WHtR are the best predictors [23–26]. In the present study, WC appeared to be a better predictor than BMI, WHR, or WHtR in women who began the study with an ideal or normal blood pressure (wider AUC), a finding that is supported by the previously published study by Panagiotakos et al. [14]. Although WC is not an index adjusted by hip size or height, it does reflect the condition of visceral obesity, which is closely related to the incidence of hypertension [27]. Also, because of the simplicity in obtaining this measurement directly, without any calculations, WC can be widely used to predict the development of hypertension.

The cut-off points for obesity indices are also controversial. The BMI cut-off points as recommended by the World Health

Table 2. Odd ratio and 95% confidence interval for progression to hypertension in both groups.

Anthropometric indices	Quartile	Range (min, max)	No. of subjects	Without adjusting			Adjusting for age, UA, FBG, PBG, LDL-C family history and smoking		
				OR	95% CI	P value	OR	95% CI	P value
Group 1									
WC (cm)	1	60, 74	76	1.000	–	–	1.000	–	–
	2	75, 81	94	2.079	0.392–11.026	0.390	1.606	0.280–9.221	0.595
	3	82, 85	82	3.453	0.694–17.172	0.130	2.544	0.472–13.714	0.278
	4	86, 106	92	8.387	1.871–37.584	0.005	6.363	1.287–31.454	0.023
BMI (kg/m ²)	1	16.42, 21.47	91	1.000	–	–	1.000	–	–
	2	21.48, 23.03	81	0.623	0.176–2.213	0.465	0.648	0.182–2.312	0.504
	3	23.05, 24.98	86	1.231	0.426–3.553	0.701	1.250	0.432–3.616	0.680
	4	24.99, 42.29	86	1.946	0.728–5.201	0.018	1.956	0.731–5.232	0.019
WHR	1	0.706, 0.790	86	1.000	–	–	1.000	–	–
	2	0.791, 0.827	87	1.250	0.324–4.822	0.746	1.264	0.327–4.888	0.734
	3	0.828, 0.862	87	1.794	0.506–6.365	0.366	1.773	0.499–6.307	0.376
	4	0.863, 1.215	84	4.457	1.413–14.053	0.011	4.369	1.376–13.873	0.012
WHtR	1	0.394, 0.467	88	1.000	–	–	1.000	–	–
	2	0.469, 0.497	80	1.889	0.437–8.171	0.395	2.790	0.509–15.274	0.237
	3	0.500, 0.532	88	3.228	0.437–8.171	0.087	3.799	0.729–19.786	0.113
	4	0.533, 0.665	88	5.360	1.483–19.382	0.010	6.249	1.231–31.718	0.027
Group 2									
WC (cm)	1	64, 79	77	1.000	–	–	1.000	–	–
	2	80, 84	93	1.728	1.431–19.126	0.128	1.747	0.842–3.624	0.134
	3	85, 91	107	1.287	0.637–2.597	0.482	1.102	0.526–2.309	0.798
	4	92, 125	98	3.812	1.935–7.511	<0.001	3.460	1.673–7.156	0.001
BMI (kg/m ²)	1	16.82, 22.86	92	1.000	–	–	1.000	–	–
	2	22.89, 24.92	97	0.981	1.935–7.511	0.954	0.895	0.460–1.742	0.744
	3	24.97, 27.18	89	1.047	0.546–2.009	0.890	0.949	0.473–1.906	0.884
	4	27.24, 46.61	97	2.319	1.262–4.262	0.007	2.253	1.174–4.325	0.015
WHR	1	0.691, 0.818	93	1.000	–	–	1.000	–	–
	2	0.819, 0.852	92	0.958	0.494–1.858	0.900	0.974	0.486–1.955	0.942
	3	0.853, 0.879	96	1.184	0.494–1.858	0.605	1.104	0.556–2.194	0.777
	4	0.880, 1.141	94	2.755	0.494–1.858	0.001	2.599	1.320–5.116	0.006
WHtR	1	0.386, 0.494	95	1.000	–	–	1.000	–	–
	2	0.497, 0.530	95	0.946	0.494–1.813	0.868	0.875	0.447–1.714	0.698
	3	0.531, 0.568	92	1.289	0.684–2.43	0.433	1.048	0.534–2.057	0.892
	4	0.569, 0.791	93	2.408	1.306–4.441	0.005	1.948	1.010–3.759	0.047

Group 1, ideal blood pressure group; Group 2, pre-hypertensive group. WC – waist circumference; BMI – body mass index; WHR – waist-hip ratio; WHtR – waist-height ratio; CI – confidence interval; UA – uric acid; FBG – fasting blood glucose; PBG – postprandial blood glucose; LDL-C – low-density lipoprotein cholesterol.

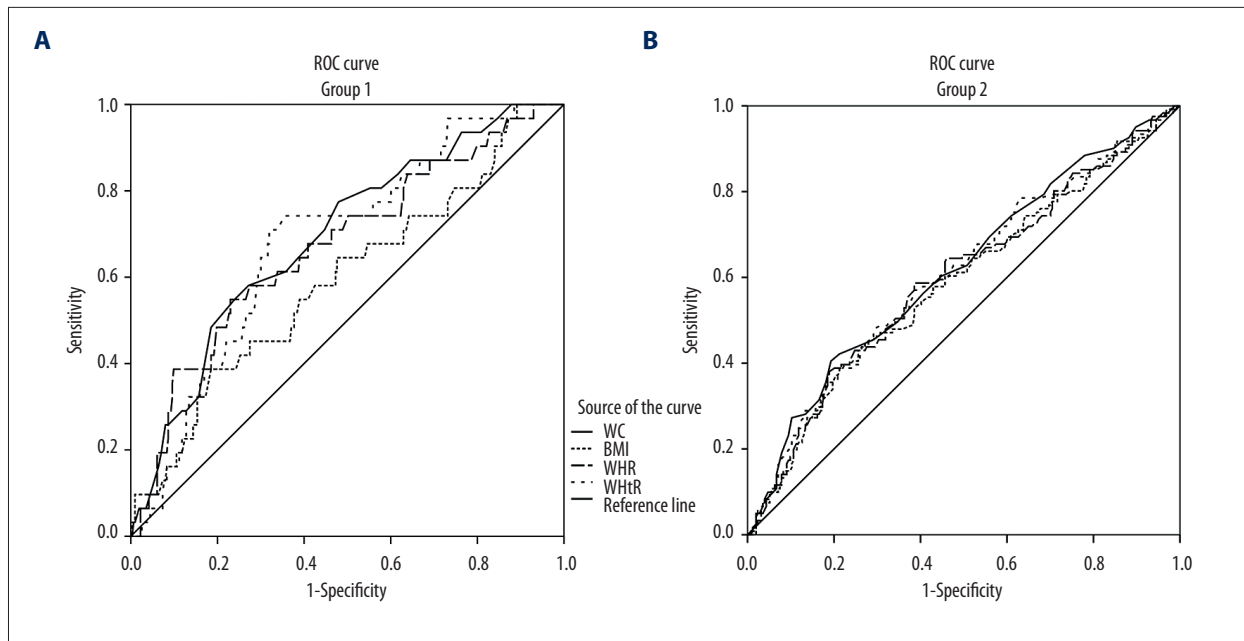


Figure 2. ROC curves for anthropometric indices in relation to incidence of hypertension. Group 1, ideal blood pressure group; Group 2, pre-hypertensive group. ROC – receiver operating characteristic; WC – waist circumference; BMI – body mass index; WHR – waist-hip ratio; WHtR – waist-height ratio.

Table 3. AUC and optimal cut-off points of anthropometric indices in relation to incidence of hypertension in both groups.

Anthropometric indices	AUC	95% CI	P value	Cut-off point	Sensitivity (%)	Specificity (%)	Youden Index
Group 1							
WC (cm)	0.692	0.598–0.787	<0.001	84.5	0.581	0.272	0.309
BMI (kg/m ²)	0.593	0.484–0.702	0.087	25.4	0.387	0.185	0.202
WHR	0.671	0.568–0.775	0.002	0.859	0.548	0.230	0.318
WHtR	0.682	0.591–0.772	0.001	0.516	0.710	0.319	0.390
Group 2							
WC (cm)	0.615	0.553–0.677	<0.001	91.5	0.405	0.193	0.212
BMI (kg/m ²)	0.587	0.525–0.650	0.006	26.2	0.446	0.272	0.175
WHR	0.597	0.534–0.660	0.002	0.862	0.587	0.386	0.201
WHtR	0.604	0.542–0.667	0.001	0.550	0.479	0.291	0.188

Group 1, ideal blood pressure group; Group 2, pre-hypertensive group. WC – waist circumference; BMI – body mass index; WHR – waist-hip ratio; WHtR – waist-height ratio; AUC – area under the receiver operating characteristic curve; CI – confidence interval.

Organization (WHO) are 25.0–29.9 kg/m² as being overweight, and ≥30 kg/m² for obesity [28]. While in China, the Working Group on Obesity in China (WGOC) recommends >24.0 kg/m² as being overweight [29]. The WGOC has also developed WC cut-off points for the general Chinese population, which are 85.0 cm for men and 80.0 cm for women [29]. According to

WHO, a WHR >0.9 for men and >0.85 for women is defined as abdominal obesity [30]. The study by Shao et al. [31], in a Chinese population, applied an optimal WHtR cut-off point of 0.5 for both sexes. Other studies have reported other values for anthropometric cut-off points [11,32,33].

In the present study, the optimal cut-off points for anthropometric indices in women with an ideal, or normal, blood pressure were 84.5 cm for WC, 25.4 kg/m² for BMI, 0.859 for WHR, and 0.516 for WHtR, respectively. These findings are slightly higher than those reported by previously published studies. This difference could be related to the fact that the present study specifically recruited middle-aged women, between 40–70 years, and age group that was higher than in previous studies, which mainly included participants ≥18 years. Furthermore, the cut-off point for WHtR appeared to have the highest Youden's index among the four indices in the present study (0.390), which indicated that the optimal cut-off point for WHtR had a better sensitivity and specificity for predicting the development of hypertension in women who initially has an ideal, or normal, blood pressure.

A previously published study by Hu et al. showed that the incidence of hypertension during a six-year follow-up in patients with normal blood pressure (<120/80 mmHg) and pre-hypertension (120–139/80–89 mmHg) was 9.8% and 32.7%, respectively [34]. Similarly, the findings of the present study showed that during the two-year follow-up period, the incidence of hypertension in the ideal blood pressure group (Group 1) and the pre-hypertensive group (Group 2) were 9.0% and 32.3%, respectively. Therefore, these findings have implications for the primary prevention of the development of hypertension in a pre-hypertensive population and with reduction of the incidence of hypertension in this population of middle-aged women. However, to the best of our knowledge, few studies have investigated the anthropometric indices and the optimal cut-off values in predicting hypertension in pre-hypertensive populations.

Some previously published studies have shown that WC, BMI, WHR, and WHtR were associated with the incidence of hypertension in pre-hypertensive populations [14,15]. In the present study, logistic regression analysis showed that all the four anthropometric indices studied were associated with the future development of hypertension in pre-hypertensive women during a two-year follow-up period. The findings of the study showed that the AUC for WC, BMI, WHR, and WHtR in pre-hypertensive women (which were 0.615, 0.587, 0.597, and 0.604, respectively) were lower than the AUC in women with a baseline ideal, or normal, blood pressure (which were 0.692, 0.593, 0.671, and 0.682, respectively). These findings indicate that anthropometric indices appear to be better in predicting the development and future incidence of hypertension in subjects with a baseline ideal, or normal, blood pressure. Furthermore, the WC in both the ideal blood pressure group (Group 1) and the pre-hypertensive group (Group 2) was still the better anthropometric indicator for the prediction of the development of hypertension (with a wider AUC). However, comparing the four obesity indices (WC, BMI, WHR, and WHtR) in relation to the population with an initial ideal, or normal, blood pressure, WC performed less well the pre-hypertensive population (Group 2).

Also, the findings of the present study showed that the optimal cut-off values for WC (91.5 cm), BMI (26.2 kg/m²), WHR (0.862), and WHtR (0.550) in pre-hypertensive women (Group 2) were higher than those in women with a baseline ideal, or normal, blood pressure (Group 1) with values of WC (84.5 cm), BMI (25.4 kg/m²), WHR (0.859), and WHtR (0.516), and were even higher than in the populations with an initial normal blood pressure in previously published studies. Because of these varied findings, it is likely that different standards might have been used for the definitions or measurements of anthropometric indices, classification of pre-hypertensive individuals, and different age groups, and ethnicities in different studies. However, in the present study, the cut-off values for all four of the anthropometric indices (WC, BMI, WHR, and WHtR) had a lower Youden's index in the pre-hypertensive group (Group 2), which may indicate that the value of cut-off points for the anthropometric obesity indices were likely to be lower in pre-hypertensive women.

This study had several limitations. A cohort study was undertaken in an urban Chinese ethnic population of middle-aged women, aged between 40–70 years, which was a very specific study population. Whether the same conclusions can be applied to other ages, sex, or ethnic groups is unknown. Also, because of financial limitations, the size of the research sample was small, and for future studies, a larger participant sample size would be recommended. This study only used the baseline anthropometric data and did not consider variations in the anthropometric obesity parameters during the two-year follow-up, as recommended in the JNC 7 report [2]. The definition of 'pre-hypertension' in this study was equivalent to that of mildly elevated blood pressure or Stage 1 hypertension in the 2017 American College of Cardiology and American Heart Association (ACC/AHA) guidelines, which recommend non-pharmacological therapy in these cases [3]. Despite these limitations, the findings of this study are meaningful regarding their implications for the prevention of hypertension and the reduction in the incidence of hypertension in women in the age group and population studied.

Conclusions

In a cohort of middle-aged women in China, anthropometric indices of obesity, particularly the measurement of waist circumference (WC), were predictive of the development of hypertension during a two-year follow-up period, and therefore of the incidence of hypertension developing in this population. Although this study specifically included middle-aged Chinese women and had some limitations, the study findings demonstrated the value of anthropometric obesity indices as predictors of the development of hypertension. Also, the optimal cut-off values of anthropometric obesity indices

in pre-hypertensive (ACC/AHA Stage 1 hypertensive) women were much higher compared with women who had a normal baseline blood pressure. The findings of the study also highlight the importance of controlling obesity in pre-hypertensive middle-aged women in the primary prevention of hypertension.

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