The Effect of Lipid Accumulation Product and Its Interaction With Family History of Hypertension on Hypertension Risk in Population With Nondiabetic in Eastern China: A Cross-sectional Study

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Abstract

Background: Lipid Accumulation Product (LAP) was proposed as a useful indicator of visceral obesity, the visceral obesity and cardiovascular diseases are closely related. However, the empirical evidences of LAP and hypertension (HTN) are limited. Our study sought to assess the risk factors of HTN and prehypertension (PHT), and provide an insight into the possible interacting influences of LAP with family history of HTN on the risk of HTN in the nondiabetic Eastern Chinese population.

Methods: A large cross-sectional study was conducted in community health service centers in urban Bengbu of Anhui province, China. All elderly person aged 45 years and older were performed an interview questionnaire, physical measurements and biochemical indicators examinations by trained staffs. Common indexes to screen obese persons such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR) and LAP were calculated. Multivariate logistic regression was used to test the prevalence of HTN and PHT in relation to each quartile increase in LAP level and family history of HTN. The receiver operating characteristic (ROC) analysis was applied to calculate the best cut-off value of LAP and identify the superior obesity indicator. The interaction effects were evaluated by relative excess risk of interaction (RERI), attributable proportion due to interaction (AP) and synergy index (SI).

Results: 7733 subjects were enrolled in our study, the overall prevalence rates of normotension, PHT and HTN were 38.1%, 37.1% and 24.8%, respectively. The prevalence of HTN increased rapidly across LAP quartiles in males and females, the LAP values in the top quartile were significantly higher than those in the bottom quartile (31.8% vs. 17.6% in males, p for trend <0.001; 31.4% vs. 18.8% in females, p for trend <0.001). The AUC value of LAP were superior to BMI in males (Z=6.627, p<0.001) and females (Z=8.045, p<0.001). Multinomial logistic regression analysis showed that compared with subjects in LAP quartile 1, those in quartile 3 (OR: 1.612, 95% CI: 1.386-1.876) and quartile 4 (OR: 1.942, 95% CI: 1.673-2.253) had significantly higher risk of HTN (p for trend<0.001) after adjusting for confounding factors. A significant interaction was observed between LAP and family history of HTN in males (AP: 0.1663, 95% CI: 0.0027-0.3299; SI: 1.4035, 95% CI: 1.0597-1.8590) and females (RERI: 1.4109, 95% CI: 0.1455-2.9674; AP: 0.1664, 95% CI: 0.0088-0.3240; SI: 1.3884, 95% CI: 1.0565-1.8245).

Conclusion: LAP is a simple and convenient index to predict the HTN risk, higher LAP values have relatively associated with higher blood pressure (BP). The results demonstrated that interactive effects of LAP with family history of HTN may synergistically influence the development of HTN.

Background

Hypertension (HTN) is a major worldwide public health challenge and regarded as a significant risk factor for cardiovascular diseases (CVD) [1-2]. Meanwhile, HTN is one of the biggest contributor to the increased social medical expenditure in the elderly person in addition to mortality and other negative consequences [3]. The World Health Organization (WHO) reported that the number of hypertensive adults in the world will increase to 1.56 billion in 2025 and to be more worrying in middle- and low-income countries [4-5]. China, the world's largest developing country, with the rapid aging process and nutrition transition over the past few years, the prevalence of HTN has risen remarkable. The prevalence rate of HTN in China was reported as 27.8% in 2017 [6]. However, the proportion did not include the prehypertension (PHT). PHT, designated as 120 mmHg < systolic blood pressure (SBP) < 140 mmHg or/and 80 mmHg < diastolic blood pressure (DBP) < 90 mmHg [7]. PHT individuals were more likely to develop HTN compared with those normotension and associated with increased risk of cardiovascular diseases incidence and morbidity [8-10]. Several surveys revealed that the prevalence of PHT may be 20% in the general adult population and 50% in the middle-aged population [11-12]. Therefore, the effective predictors and risk factors of HTN and PHT are essential to search for reducing the cardiovascular morbidity and health burden.

Numerous studies agreed that individuals having a family history of HTN and obesity were more likely to develop HTN [13-15], the etiology of family history was assumed to be that patients with family history of HTN have increased sympathetic and decreased cardiac parasympathetic activity at rest compared with those no family history subjects, sympathetic modulation has been found increased in both HTN and PHT individuals [16]. However, when it comes to obesity, body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) are most common indexes to assess obesity [17]. BMI can reflect the degree of overweight and obesity, but cannot differentiate the abdominal obesity [18], WC and WHtR can reflect the abdominal fat distribution, but cannot distinguish between visceral and subcutaneous fat [19]. Nevertheless, HTN and other cardiovascular risks are directly determined by visceral fat rather than subcutaneous fat [20]. Therefore, a new and convenient indicator is necessary to search for predicting visceral adipose tissue for large-scale epidemiological investigations [21].

Lipid Accumulation Product (LAP), a new obesity indicator calculated by using triglycerides (TG) level and WC, was proposed as a useful index of visceral fat by Kahn in 2005 [22]. A prospective study demonstrated that the LAP was found to be a reliable predictor to evaluate cardiovascular risk in a healthy population [23]. Several cross-sectional studies indicated that LAP significantly associated with insulin resistance and diabetes risk [24-26]. Bozorgmanesh M *et al* [27] confirmed that high LAP value was a predictor of incident CVD in a cohort study for 8.6 years in Tehran. LAP had also been shown to predict blood pressure in 21,572 Japanese men [28]. Several studies in China also have investigated the association between LAP and HTN [19, 29], as a largest developing country in the world, China has faced rapid economic development and met huge social medical burdens. Anhui province, located in the east of China, has experienced rapid aging process, unhealthy diet intake, physical inactivity and so on. As such, one of Anhui's newest challenges is adapting to its formidable chronic diseases.

Some studies reported that HTN and type 2 diabetes mellitus (T2DM) may co-exist, in patients with HTN the prevalence of T2DM was as high as 30% [30]. Furthermore, as the polygenic related inheritance characteristic of HTN, the combined impact of risk factors can aggravate this disease [31]. However, the interaction analysis between family history of HTN and obesity indices has not been determined. Considering the confounding effect of diabetes, we performed a community-based study in nondiabetic population to investigate the interactive effects between LAP and family history of HTN in Anhui province.

Thus, in this study, the primary purpose is to explore the relationship between LAP and risk of HTN, PHT in Anhui province. The secondary purpose is to compare the predictive abilities of LAP, BMI, WC and WHtR on the risk of HTN in males and females. The third purpose is to evaluate the possible interactive effects between LAP and family history of HTN to predict the HTN and PHT risk in the older adult population in Bengbu city, Anhui province.

Methods

Study population

This community-based cross-sectional study was conducted in urban Bengbu of Anhui province, China. The survey was conducted from July to November 2018 involving community-dwelling elderly residents aged 45 years and above. The sample was randomly selected by a multistage and stratified random sampling from Longzihu district in Bengbu. Inclusion criteria: (1) lived more than 6 months in the selected communities; (2) ≥45 years old; (3) agree to cooperate with this survey. The study was approved by Bengbu Medical College Ethics Committee.

A total of 9477 individuals were investigated, and there were 7733 eligible subjects actually participated in our study. All participants had written the informed consent.

Data collection

The recruited participants performed a face-to-face questionnaire interview by trained staffs. Sociodemographic information included as follows: sex, age, educational level ("primary school or below" or "high school or above"), marital status ("currently married" or "not"), smoking (smoking > 1 cigarette per day for at least 6 months), drinking (drinking > 30mL alcohol per week for at least one year) and family history of HTN (both parents or one parent diagnosed as HTN) [32].

Anthropometric measurements and laboratory examinations

Standing height, body weight were measured by trained staffs in lightweight clothing to the nearest 0.1cm and 0.1kg, BMI was calculated as weight (kg)/height squared (m^2) [33]. WC was measured at the umbilical level, WHtR was calculated as WC (cm) divided by the height (cm).

The blood samples were collected for laboratory examinations after at least 8 hours of overnight fasting, the fasting blood glucose, total cholesterol (TC) and triglyceride (TG) levels were tested for analyze.

Blood pressure (BP) was checked by standardized methods using mercury sphygmomanometer in the right arm, each subject was required for at least 10 minutes rest before the measurement of BP, the average results of the thrice measurements were adopted in our study.

Diagnostic criteria

Abdominal obesity diagnosed with WHtR ≥ 0.5 [34]. The diagnostic criteria of HTN and PHT were as follows: if SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg then diagnosed with HTN; if 120 mmHg < SBP < 140 mmHg and/or 80 mmHg < DBP < 90 mmHg then diagnosed with PHT; Diabetes diagnosed with fasting plasma glucose (FPG) ≥7.0 mmol/L [35].

The calculate criteria of LAP were as follows: males was calculated as [WC (cm) -65]×[TG (mmol/L)]; females was calculated as [WC (cm) -58]×[TG (mmol/L)] [22].

Statistical analysis

Firstly, the distribution of quantitative and qualitative data of the participants were presented as mean ± standard deviation (SD) and numbers with percentages respectively. Comparisons of basic characteristics between different groups were analyzed using the chi-square test for categorized variables and one-way ANOVA test or Kruskal-Wallis H test for continuous variables. Secondly, LAP was presented as quartiles (Q_1-Q_4), and multivariate logistic regression was used to test the prevalence of HTN and PHT in relation to each quartile increase in LAP level. Thirdly, the receiver operating characteristic (ROC) curves were drawn by the MedCalc Version 18 (DEMO) software, in order to identify the superior obesity index and the best cut-off value of LAP. Finally,

the interaction effects between LAP and family history of HTN was assessed by the three indicators: (1) the relative excess risk of interaction (RERI=OR_{11}-OR_{10}-OR_{01}+1); (2) the attributable proportion due to interaction (AP=[OR_{11}- OR_{10}-OR_{01}+1]/OR_{11}); (3) the synergy index (SI=[OR_{11}-1]/[OR_{01}-1]+[OR_{10}-1]). All above indicators were calculated using an excel table designed by Andersson *et al*[36-37]. IBM SPSS Statistics (version 22.0) was performed for statistical procedures.

Results

1 General Characteristics

A total of 7733 residents (3275 men and 4458 women) were enrolled in our study, the mean age was (62.90±6.16) year for men and (62.87±6.15) year for women. The total prevalence rates of normotension, PHT and HTN were 38.1%, 37.1% and 24.8%, respectively. No significant differences were found in prevalence of HTN and PHT between men and women (25.6% *vs* 24.2%, p=0.178; 38.2% *vs* 36.2%, p=0.080). Significant differences were observed in sex (p=0.013), age (p<0.001), marital status (p=0.012), smoking (p=0.001), drinking (p<0.001) and family history of HTN (p<0.001) among normotension, PHT and HTN groups. For anthropometric indices, significant differences were presented in BMI (p<0.001), WC (p<0.001), WHtR (p<0.001), abdominal obesity (p<0.001)

and LAP (p<0.001) between the groups. For laboratory indices, significant differences were presented in SBP (p<0.001), DBP (p<0.001), FPG (p<0.001) and TG (p<0.001) between the groups. However, no significant differences were found in education level (p=0.605) and TC (p=0.522). The basic characteristics of the study subjects were shown in Table 1.

2 LAP and risk factors of HTN and PHT

From Q_1 to Q_4 of LAP, the prevalence of HTN in males was 17.6%, 24.0%, 28.8% and 31.8%, respectively (p for trend <0.001), while in females was 18.8%, 19.0%, 27.7% and 31.4%, respectively (p for trend <0.001). However, the prevalence of PHT in males (p=0.568) and females (p=0.202) were not statistically significant. The quartile of LAP level in males and females were demonstrated in Figure 1 and Figure 2.

3 AUC of LAP and other obesity indexes to predict HTN risk

As showed in Table 3 and Figure 3 and Figure 4, we listed the predictive abilities of obesity indexes and LAP for HTN risk. The AUC value of LAP was 0.626 (95%CI: 0.609-0.643) in males and 0.638 (95%CI: 0.623-0.652) in females. BMI, WC and WHtR were inferior to LAP in AUC value both in males and females. For males, the AUC of LAP was significantly higher than that of BMI (Z=6.627, p<0.001) and WHtR (Z=4.767, p<0.001); As for females, the AUC of LAP was significantly different with BMI (Z=8.045, p<0.001) and WC (Z=4.215, p<0.001) and WHtR (Z=6.345, p<0.001). The best cut-off points of LAP for predicting HTN were 26.40 in males and 33.88 in females.

4 Quartiles of LAP and risk of HTN and PHT in population with nondiabetic by logistic regression analysis

As presented in Table 4, multinomial logistic regression analysis showed that compared with subjects in LAP quartile 1, those in quartile 3 (OR: 1.612, 95% CI: 1.386-1.876) and quartile 4 (OR: 1.942, 95% CI: 1.673-2.253) had significantly higher risk of prevalent HTN (p for trend<0.001), after adjusting for sex, age, family history of HTN and so on, the risk of HTN significantly increased in population in the fourth quartile (OR: 1.326, 95% CI: 1.101-1.596) than those in the first quartile. Compared with those had no family history of HTN, participants with family history of HTN had higher risk of being HTN (OR: 1.283, 95% CI: 1.098-1.499) and PHT (OR: 1.171, 95% CI: 1.015-1.350) after adjusting the confounding factors (p for trend<0.05). No statistically significant relationship between LAP level and PHT risk was observed. The results also showed that when treated the LAP as a continuous variable, a per unit increase of LAP would increase the risk of HTN by 1.165-fold (95% CI: 1.110-1.222), no significant difference was discovered between LAP and PHT risk (OR: 1.031, 95% CI: 0.985-1.079).

5 The interaction analysis for HTN risk

The interaction analyses between LAP and family history of HTN were presented in Table 5, the subjects were classified into four subgroups based on LAP level by the cut-off values and family history factor. After adjusting for confounding factors, the male participants with higher LAP level possessed higher risk of getting HTN (OR for negative family history: 1.630, 95% CI: 1.375-1.933 *vs* OR for positive family history: 2.276, 95% CI: 1.716-3.019). In female participants, the adjusted OR of HTN was higher in low-LAP and family history subgroup (1.543, 95% CI: 1.104-2.155) as compared with low-LAP and non-family history subgroup. Meanwhile, the participants with higher LAP level and family history simultaneously revealed the highest OR (2.125, 95% CI: 1.644-2.746).

A significant interaction was found in males between LAP and family history on risk of HTN in two indicators (AP: 0.1663, 95% CI: 0.0027-0.3299; SI: 1.4035, 95% CI: 1.0597-1.8590), the AP value indicated that 16.63% of HTN exposed to the two risk factors was attributable to the interaction. Moreover, there also a significant interaction between LAP and family history on HTN in all indicators in females: RERI: 1.4109, 95% CI: 0.1455-2.9674; AP: 0.1664, 95% CI: 0.0088-0.3240; SI: 1.3884, 95% CI: 1.0565-1.8245, the RERI value revealed that there would be 1.4109 relative excess risk due to the interaction.

Discussion

With the rapid social and economic development, the number of HTN and PHT patients in China has become considerably massive [38-40]. The prevalence of HTN (24.8%) in our study was consistent with that survey conducted in Zhejiang province (24.59%) [41], higher than that in Guangdong province (22.03%) [19]. Also, the overall prevalence of PHT in this study was 37.1%, higher than that results carried out in Jiangxi province (32.3%) [9] and Zhejiang province (32.1%) [41], but lower than the rates in Qinghai province (41.3%) [11] and Hubei province (42.2%) [39]. The prevalence of HTN and PHT in the northwest and central regions were higher than that in the southeast region, the northwest region has experienced slow economic development, its residents shows a high intake of rice, liquor, brined vegetables and so on, which is an essential factor of blood pressure elevation [42]. Numerous studies have demonstrated that subjects with PHT would have a significant higher chance to develop to HTN within a few years [43-44], meanwhile, elevated BP has serious consequences on person health such as stroke, atherosclerotic plaque and so on [45]. In this present study, we indicated that BMI, WC and WHtR were significant risk factors of HTN and PHT in both genders, suggesting that more attention should be paid to overweight and obese individuals.

Accumulating evidences had shown that the harm of fat distribution location is greater than the total fat overall [46-47]. Visceral fat can activate the renin-angiotensin-aldosterone system, and the lipolytic activity of visceral fat cells was stronger than that of subcutaneous fat cells [48]. Nevertheless, common obesity indicators, such as BMI, WC and WHtR, can predict those whether or not with normal weight, but cannot accurately distinguish visceral fat and subcutaneous fat. However, visceral fat may be more closely related with the incidence of cardiovascular diseases [49-50]. LAP, combined with WC and TG, was proved to be a new obesity indicator to predict visceral fat. As a continuous variable, LAP is a simply new indicator for identifying the subjects who having cardiovascular risks. A cross-sectional study conducted by Motamed N *et al.* suggested that participants with high LAP had a risk of stroke increased by 67% compared with those low LAP subjects [51]. Kahn indicated that LAP might be a better predictor in discriminating visceral obesity [22], and several studies had found the superiority of LAP over BMI and WC for detection of HTN and PHT [45, 52]. According to our study, the LAP level was significantly higher in the HTN [34.56(21.28, 51.80)] and PHT [29.70(18.70, 46.40)] group than in the normotension [26.60(16.50, 42.70)] group (P<0.001) (Table 1). The prevalence of HTN gradually increased across LAP quartiles in males and females, the values in the fourth quartile of LAP were significantly higher than those

in the first quartile (31.8% vs. 17.6% in males, 31.4% vs. 18.8% in females) (Figure 1 and Figure 2), and this conclusion concur with previous findings that reported in China [52-53].

The study showed that the AUC of LAP was 0.626 in males and 0.638 in females, all of which were superior to that of BMI, WC and WHtR in participants, indicating that for predicting HTN, LAP had more power compared with BMI, WC and WHtR (Table 3). Furthermore, the identified cutoff value of LAP was 26.40 (sensitivity, 48.45%; specificity, 71.15%) in males and 33.88 (sensitivity, 65.96%; specificity, 54.37%) in females, a number of findings are consistent with our study [19, 44]. A survey in Urumqi, China found that the cutoff value of LAP index to predict cardiovascular disease risk was 38.41 [54], and an investigation conducted in northeastern Brail found that LAP had more sensitivity to predict cardiovascular risk and the appropriate predictive accuracy was 37.9 [55]. LAP provides an effective screening tool and has a high reproducibility to assess the whole-body lipid accumulation and promote the identification of subjects with an excess of visceral adipose tissue. The optimal cutoff value of LAP to predict cardiovascular risk is still controversy, so large sample size surveys stratified into sex, age and obesity categories (normal, overweight or obesity) are needed to conduct.

As expected, a significant association was found between LAP and HTN in our study, after adjusting for confounding factors, the subjects in quartile 4 (OR: 1.326, 95% CI: 1.101-1.596) had significantly higher risk of prevalent HTN (*p* for trend<0.001) compared with those in quartile 1 (Table 4), the result have demonstrated that LAP is a simply and reliable diagnostic index of HTN. Multinomial logistic regression analysis also revealed that the risk of HTN and PHT in the group with family history were 1.283 and 1.171 times higher than those in no family history group after adjusting for confounding factors. High BP increases the risk of CVD and a family history of HTN doubles the risk, the interaction between genes and environment may aggravate this risk. A population-based study showed that compared with no family history individuals (24.4%), the prevalence of HTN in subjects with family history was 29.3% [56].

The present study indicated that a remarkable interaction exists between LAP and family history of HTN in regard to HTN risk in both genders. Our interaction analysis showed that the synergy index of LAP and family history on HTN risk is 1.4035 (1.0597-1.8590) in males and 1.3884 (1.0565-1.8245) in females (Table 5), the result was consistent with those in studies by Zhong C *et al* [57], Song J *et al* [58] and Bazyar H *et al* [59], all of which had demonstrated that obesity and family history have several common mechanisms to increase BP, such as increasing oxidative stress and inhibiting vascular reflex vasodilation [45]. It was suggested by JNC-7 that anthropometric data and blood lipid parameters might influence the incidence of HTN and PHT directly.

There are some limitations in our study. Firstly, as a cross-sectional study, the causal association between LAP, family history of HTN and HTN, PHT can not be determined. Secondly, the population of our survey selected from Bengbu city, only can partially represent the general population of Anhui province, but can not fully represent the center region of China. Thirdly, the intake of lipid lowering drugs of participated individuals was not investigated.

Conclusions

In conclusion, HTN and PHT are prevalent in nondiabetic Anhui adults, LAP is an effective and simple indicator to predict the HTN risk, and higher LAP levels have relatively higher BP. LAP with family history of HTN may have an interactive effect on the development of HTN. Further cohort studies with more research regions and population are urgent to survey the result, and the mechanisms of LAP and HTN risk need to be elucidated to support more prevention strategies for HTN.

Abbreviations

LAP: Lipid accumulation product; HTN: hypertension; PHT: prehypertension; BMI: Body mass index; WC: Waist circumference; WHtR: Waist to height ratio; ROC: Receiver operating characteristic; RERI: Relative excess risk of interaction; AP: Attributable proportion due to interaction; SI: Synergy index; CVD: cardiovascular diseases; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; TC: Total cholesterol; TG: Triglycerides; SD: Standard deviation; OR: Odds ratio; CIs: Confidence interval.

Declarations

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Authors' contributions

SL designed the research. SL drafted the manuscript. SLN and SL collected the data. SL, SYQ, WJC and HZY performed the statistical analysis and interpreted the results. SLN helped prepare the methods section. SL and SYQ revised the manuscript critically. All authors read and approved the final manuscript.

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Ethics approval and consent to participate

This study was approved by the Ethics Committee of Bengbu Medical College. Written informed consent was obtained from all participants.

Consent for publication

Not Applicable.

Competing interests

The authors report no conflicts of interest.

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Tables

Table 1 Basic characteristics of the study subjects

Variables	Normotension (n=2947)	PHT (n=2867)	HTN (n=1919)	$c^2/F/H$	*P*-value
Sex [male n(%)]	1186(40.2)	1251(43.6)	838(43.7)	8.656	0.013[2]
Age (years)	62.22±5.86	62.87±6.20	63.92±6.39	44.993	<0.001[1]
Education level [n(%)]				1.006	0.605[2]
Primary school or below	2553(86.6)	2480(86.5)	1644(85.7)		
High school or above	394(13.4)	387(13.5)	275(14.3)		
Marital status [currently married n(%)]	2606(88.4)	2530(88.2)	1646(85.8)	8.844	0.012[2]
Smoking [n(%)]	241(8.2)	235(8.2)	213(11.1)	15.079	0.001[2]
Drinking [n(%)]	318(10.8)	295(10.3)	270(14.1)	18.098	<0.001[2]
Family history of HTN [n(%)]	492(16.7)	614(21.4)	459(23.9)	41.488	<0.001[2]
BMI (kg/m^2) [M(P_{25}, P_{75})]	23.9(21.9, 26.0)	24.4(22.6, 26.5)	24.9(22.9, 27.2)	135.763	<0.001[3]
WC (cm) [M(P_{25}, P_{75})]	84.0(78.0, 90.0)	85.0(80.0, 91.0)	88.0(82.0, 96.0)	279.343	<0.001[3]
WHtR [M(P_{25}, P_{75})]	0.52(0.48, 0.56)	0.52(0.49, 0.56)	0.55(0.51, 0.59)	297.137	<0.001[3]
Abdominal obesity [n(%)]	1140(38.7)	1180(41.2)	1099(57.3)	180.010	<0.001[2]
SBP (mmHg) [M(P_{25}, P_{75})]	120.0(115.0, 124.5)	132.5(130.0, 135.5)	149.5(144.0, 158.0)	6787.517	<0.001[3]
DBP (mmHg) [M(P_{25}, P_{75})]	75.0(70.0, 80.0)	80.0(75.0, 84.0)	85.5(80.0, 91.0)	1916.034	<0.001[3]
FPG (mmol/L) [M(P_{25}, P_{75})]	4.98(4.56, 5.50)	5.09(4.62, 5.64)	5.19(4.72, 5.74)	85.874	<0.001[3]
TC (mmol/L) [M(P_{25}, P_{75})]	4.81(4.17, 5.50)	4.82(4.18, 5.50)	4.80(4.16, 5.42)	1.299	0.522[3]
TG (mmol/L) [M(P_{25}, P_{75})]	1.16(0.82, 1.65)	1.29(0.90, 1.70)	1.25(0.90, 1.70)	33.638	<0.001[3]
LAP [M(P_{25}, P_{75})]	26.60(16.50, 42.70)	29.70(18.70, 46.40)	34.56(21.28, 51.80)	129.303	<0.001[3]

[1] Analysis of variance;

[2] Chi-square test;

[3] Kruskal-Wallis H test.

Table 2 Characteristics of the study population by LAP quartiles

Variables	LAP in males				$c^2/F/H$	*P*-value	LAP in females			
	Q_1	Q_2	Q_3	Q_4			Q_1	Q_2	Q_3	Q_4
Number	817	815	823	820	-	-	1113	1106	1119	1120
Age (years)	63.64±6.44	63.17±6.42	62.82±6.11	61.98±5.54	10.642	<0.001	63.06±6.60	62.63±5.98	62.91±6.03	62.89±5
Education level [n(%)]					22.773	<0.001				
Primary school or below	702(85.9)	698(85.6)	649(78.9)	658(80.2)			987(88.7)	983(88.9)	1001(89.5)	999(89.
High school or above	115(14.1)	117(14.4)	174(21.1)	162(19.8)			126(11.3)	123(11.1)	118(10.5)	121(10.
Marital status [currently married n(%)]	742(90.8)	753(92.4)	781(94.9)	761(92.8)	10.300	0.016	927(83.3)	922(83.4)	942(84.2)	954(85.
Smoking [n(%)]	169(19.6)	138(16.9)	153(18.6)	174(21.2)	5.127	0.163	17(1.5)	12(1.1)	18(1.6)	17(1.5)
Drinking [n(%)]	174(21.3)	193(23.7)	199(24.2)	185(22.6)	2.324	0.508	38(3.4)	31(2.8)	39(3.5)	24(2.1)
Family history of HTN [n(%)]	119(14.6)	145(17.8)	187(22.7)	224(27.3)	46.986	<0.001	135(12.1)	207(18.7)	249(22.3)	299(26.
BMI (kg/m^2) [M(P_{25}, P_{75})]	22.3(20.7, 23.9)	23.7(22.5, 25.3)	24.9(23.5, 26.6)	26.1(24.4, 28.1)	838.580	<0.001	22.2(20.4, 24.2)	24.0(22.2, 26.0)	25.0(23.2, 27.1)	26.5(24 28.8)
WC (cm) [M(P_{25}, P_{75})]	80.0(75.0, 83.0)	85.0(82.0, 90.0)	90.0(85.0, 95.0)	95.0(90.0, 100.0)	1482.638	<0.001	76.0(72.0, 80.0)	82.0(78.0, 86.0)	86.0(82.0, 92.0)	91.0(86 98.0)
WHtR [M(P_{25}, P_{75})]	0.47(0.45, 0.50)	0.51(0.49, 0.54)	0.54(0.51, 0.56)	0.56(0.53, 0.59)	1265.319	<0.001	0.49(0.46, 0.52)	0.53(0.50, 0.56)	0.55(0.52, 0.59)	0.59(0.5 0.63)
Abdominal obesity [n(%)]	45(5.5)	232(28.5)	455(55.3)	628(76.6)	972.99	<0.001	96(8.6)	393(35.5)	667(59.6)	903(80.
SBP (mmHg) [M(P_{25}, P_{75})]	129.0(121.0, 136.3)	131.0(122.5, 139.5)	132.0(125.0, 141.0)	133.0(125.0, 142.5)	67.666	<0.001	129.0(120.0, 136.8)	129.5(121.0, 137.5)	131.0(123.0, 141.0)	132.5(1 143.9)
DBP (mmHg) [M(P_{25}, P_{75})]	79.5(72.5, 83.0)	80.0(74.5, 85.0)	80.0(75.0, 86.0)	80.5(75.0, 86.5)	37.091	<0.001	77.5(70.5, 82.0)	79.0(72.0, 82.5)	79.0(72.5, 84.0)	80.0(75 85.0)
FPG (mmol/L) [M(P_{25}, P_{75})]	4.81(4.39, 5.37)	4.97(4.56, 5.41)	5.15(4.66, 5.72)	5.27(4.82, 5.84)	176.315	<0.001	4.87(4.47, 5.36)	5.05(4.61, 5.54)	5.18(4.70, 5.71)	5.28(4.8 5.82)
TC (mmol/L) [M(P_{25}, P_{75})]	4.28(3.72, 4.92)	4.48(3.93, 5.15)	4.70(4.10, 5.20)	4.70(4.10, 5.30)	98.267	<0.001	4.85(4.18, 5.56)	5.00(4.30, 5.70)	5.10(4.40, 5.71)	5.20(4.5 5.90)
TG (mmol/L) [M(P_{25}, P_{75})]	0.70(0.58, 0.90)	0.95(0.80, 1.20)	1.29(1.05, 1.57)	1.96(1.56, 2.70)	1932.255	<0.001	0.80(0.65, 1.00)	1.10(0.91, 1.33)	1.44(1.20, 1.70)	2.20(1.7 2.90)

LAP was grouped by quartiles in different sex in Table 2. Participants with higher LAP levels had significantly BMI (p<0.001), WC (p<0.001), WHtR (p<0.001), SBP (p<0.001), DBP (p<0.001), FPG (p<0.001), TC (p<0.001) and TG (p<0.001). The prevalence rate of family history of HTN (p<0.001) and abdominal obesity

(p<0.001) relatively elevated across LAP quartiles in both males and females. However, smoking (p=0.163), drinking (p=0.508) in males and age (p=0.421), education level (p=0.940), marital status (p=0.585), smoking (p=0.725), drinking (p=0.206) in females had no significant differences across LAP quartiles.

Table 3 The comparison of obesity indicators in predicting HTN risk

Variables	Cut-off value	Sensitivity (%)	Specificity (%)	Youden index	AUC (95%CI)	Z	p^*
Male							
BMI	24.81	49.40	60.77	0.1017	0.564(0.547-0.581)	6.627	<0.001
WC	90.0	47.85	71.07	0.1892	0.621(0.605-0.638)	1.143	0.253
WHtR	0.54	57.04	56.42	0.1346	0.580(0.563-0.597)	4.767	<0.001
LAP	26.40	48.45	71.15	0.1960	0.626(0.609-0.643)	-	-
Female							
BMI	25.71	43.48	68.70	0.1218	0.570(0.555-0.584)	8.045	<0.001
WC	86.0	51.62	67.16	0.1878	0.624(0.610-0.638)	4.215	<0.001
WHtR	0.53	59.67	55.14	0.1480	0.582(0.568-0.597)	6.345	<0.001
LAP	33.88	65.96	54.37	0.2033	0.638(0.623-0.652)	-	-

*: Compared with that of LAP.

Table 4 Quartiles of LAP and risk of HTN and PHT in population with nondiabetic by logistic regression analysis

		Quartiles of LAP				p for trend	Family history of HTN		p for trend
		Q_1	Q_2	Q_3	Q_4		No	Yes	
HTN	Unadjusted model	1.00(ref)	1.167 (0.997-1.366)	1.612 (1.386-1.876)	1.942 (1.673-2.253)	<0.001	1.00(ref)	1.407 (1.210-1.635)	<0.001
	Adjusted model [a]	1.00(ref)	1.026 (0.868-1.213)	1.254 (1.055-1.491)	1.326 (1.101-1.596)		1.00(ref)	1.283 (1.098-1.499) [b]	
	Continuous (per 1 SD)	1.165 (1.110-1.222)							
PHT	Unadjusted model	1.00(ref)	1.104 (0.969-1.258)	1.057 (0.928-1.205)	1.032 (0.905-1.177)	0.504	1.00(ref)	1.168 (1.015-1.344)	0.031
	Adjusted model [a]	1.00(ref)	1.139 (0.992-1.307)	1.141 (0.985-1.322)	1.192 (1.014-1.402)		1.00(ref)	1.171 (1.015-1.350) [b]	
	Continuous (per 1 SD)	1.031 (0.985-1.079)							

[a] Adjusted for sex, age, educational level, marital status, smoking, drinking, obesity indexes, FPG, TC, TG and family history of HTN;

[b] Adjusted for sex, age, educational level, marital status, smoking, drinking, obesity indexes, FPG, TC, TG and LAP.

Table 5 The interaction analysis of LAP and family history of HTN on risk of HTN

Variables		Case/total	OR (95% CI)	Measures of interaction
Male				
LAP[1]	Family history of HTN[2]			
-	-	1405/1731	1.00(ref.)	RERI=0.3945 (-0.1754-0.9644)
-	+	326/1731	1.141(0.755-1.724)	AP=0.1663 (0.0027-0.3299) *
+	-	1195/1544	1.630***(1.375-1.933)	SI=1.4035 (1.0597-1.8590) *
+	+	349/1544	2.276***(1.716-3.019)	
Female				
LAP[1]	Family history of HTN[2]			
-	-	1875/2295	1.00(ref.)	RERI=1.4109 (0.1455-2.9674) *
-	+	420/2295	1.543*(1.104-2.155)	AP=0.1664 (0.0088-0.3240) *
+	-	1693/2163	1.851***(1.594-2.149)	SI=1.3884 (1.0565-1.8245) *
+	+	470/2163	2.125***(1.644-2.746)	

[1] Grouped by the cut-off values in table 3.

[2] Defined as one parent or both parents having HTN.

*p<0.05; **p<0.01; ***p<0.001.

Figures

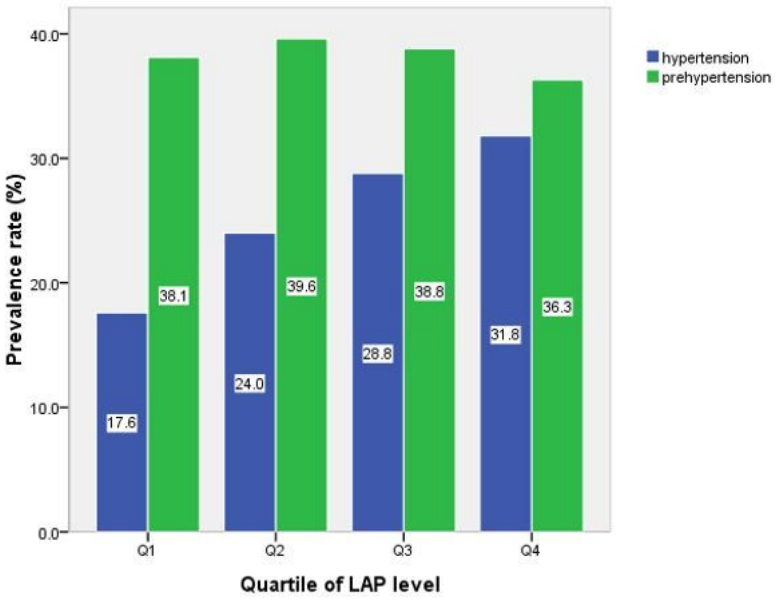

Figure 1

The prevalence of HTN and PHT across LAP quartiles in males (Q1: <15.18; Q2:15.18 to 24.99; Q3: 25.00 to 39.99; Q4: ≥40.00).

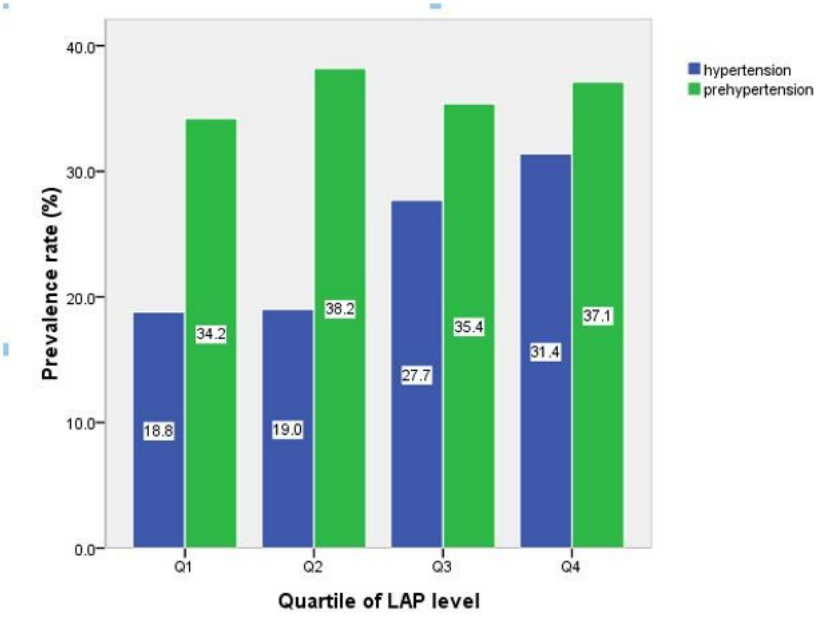

Figure 2

The prevalence of HTN and PHT across LAP quartiles in females (Q1: <21.06; Q2:21.06 to 32.99; Q3: 33.00 to 51.19; Q4: ≥51.20).

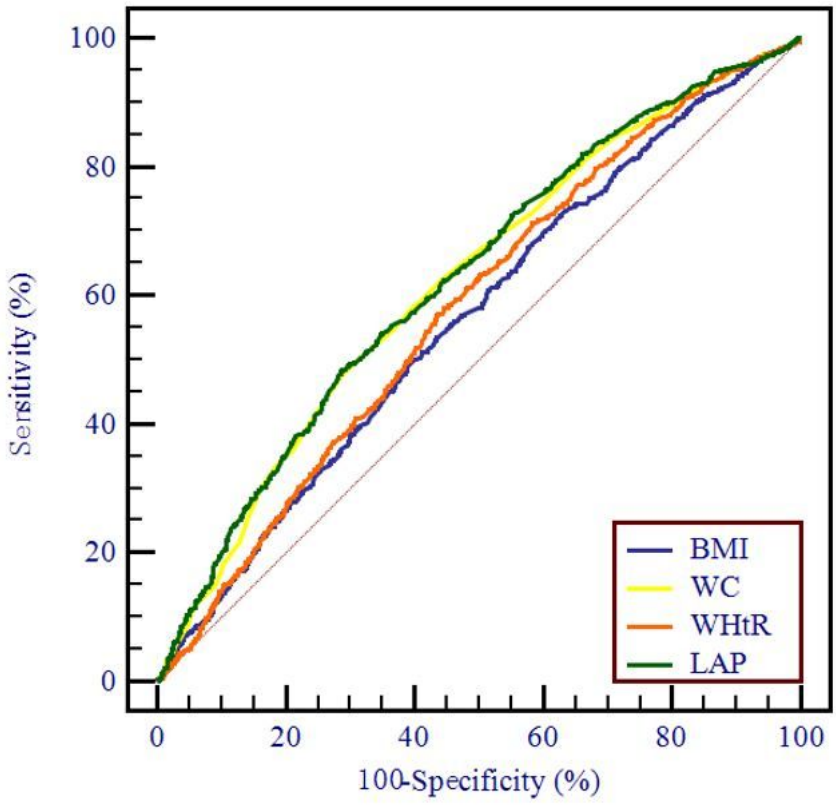

Figure 3

The ROC curve of different obesity indicators in predicting HTN risk in males.

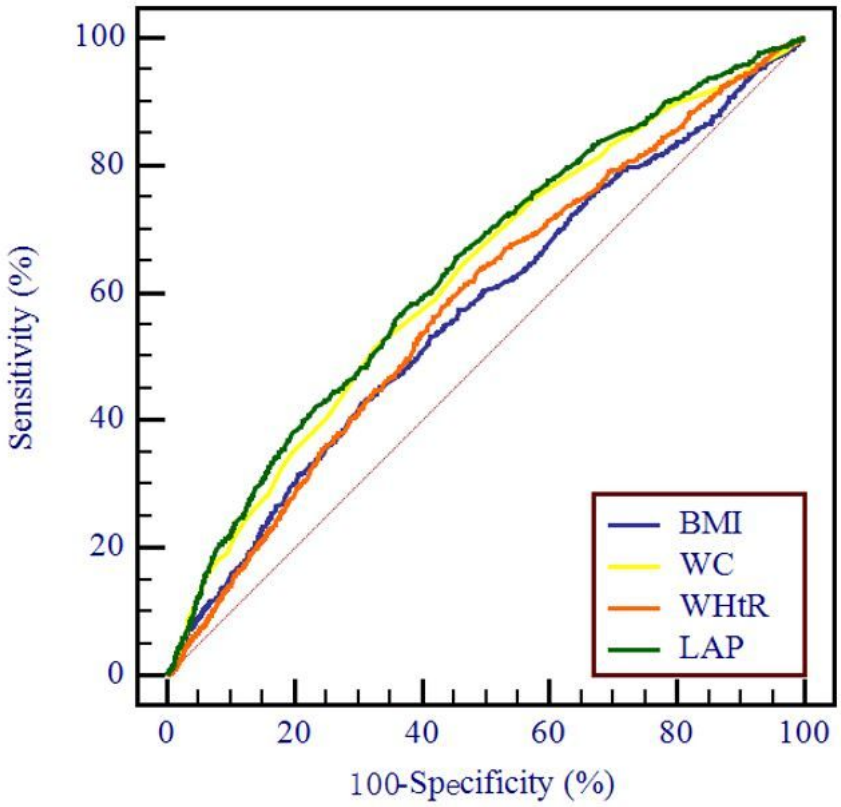

Figure 4

The ROC curve of different obesity indicators in predicting HTN risk in females