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Determination of the Best Anthropometric Index of Obesity for Prediction of Prehypertension and Hypertension in a Large Population Based Azar Cohort Study

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Abstract

Background and Objectives: Identification of strong predictors of hypertension and prehypertension in each population is important for early detection of at risk people and also planning preventive strategies. Thus, the objectives of the present study were to assess the abilities of different indices of general and central obesity in prediction of incident prehypertension and hypertension in a large population based study in Iran.

Methods: In this cross-sectional study, we evaluated the anthropometric and blood pressure measurements in 10,137 subjects (35 - 70 years). Blood pressure was measured twice with 10 minutes apart from both upper extremities separately. Height, weight, waist, and hip circumferences were measured according to the NIH guidelines. Hypertension is considered as systolic blood pressure $\geq$ 140 and/or diastolic blood pressure $\geq$ 90 mmHg or current use of antihypertensive medication for management of hypertension.

Results: The mean BMI (kg/m^2), WC (cm), waist to hip ratio (WHR), and waist to height ratio (WHtR) were 28.75 $\pm$ 4.83, 94.69 $\pm$ 11.23, 0.90 $\pm$ 0.07, and 0.58 $\pm$ 0.07, respectively. The prevalence of prehypertension and hypertension were 16.3% and 23.3%, respectively. There is a significant association between prehypertension and hypertension with all included anthropometric indices in both men and women (All P $<$ 0.001). In men, obesity increased risk of prehypertension and hypertension by 3.13 (95% CI: 2.48 - 3.94) and 4.06 (95% CI: 3.23 - 5.10). In women with WHtR $>$ 0.5 cm, the risk of hypertension increased by 6.27 (95% CI: 4.39 - 8.95) times.

Conclusions: According to the result of this large population based study, BMI is the best predictor of prehypertension and hypertension in men and also WHtR combined with BMI were the best predictor of prehypertension and hypertension in women. These findings may have important implications in using the most useful screening index for predicting hypertension in Iranian adults and also using WHtR for early detection of pre-hypertension.

Keywords: Prehypertension, Hypertension, Cohort Study, Anthropometric Measurements

1. Background

Hypertension is the global public-health problem and leading modifiable risk factor for cardiovascular disease (CVD) (1). It is predicted that in 2025, the number of adults with hypertension will increase to 1.56 billion (1). About 2/3 of the patients with hypertension are now living in developing countries (1, 2). Iran, as a Middle Eastern and developing country, faced with rapid population, social, and economic changes that lead to an upward trend in the prevalence of many CVD risk factors. A previous study has estimated that the prevalence of hypertension in Iranian adults and youth was about 22% (3-5).

Recently, the pre-hypertension rates increase worldwide along with hypertension. In this regard, the findings of Hadaegh et al. indicated that approximately half of Iranians had pre hypertension during a 10 year follow up (6). Pre-hypertensive subjects are at higher risk of hypertension and CVD compared to normotensive people (7, 8).

Risk factors including harmful use of alcohol, smoking, high dietary salt intake, excess body weight, physical inactivity, and hypercholesterolemia are among the risk factors of hypertension and prehypertension (9-11). Among these risk factors, obesity is considered as an independent risk factor for hypertension and CVD. There are a lot of studies that have assessed the relationship between differ-

ent indices of obesity (such as body mass index (BMI), abdominal obesity, etc) and hypertension. Although previously it has been shown that the prevalence of hypertension increases with general and central obesity, however, these studies mostly considered BMI and waist circumference (WC) as obesity indices and other predictors of cardiovascular disease were rarely investigated and conflicted results were also reported (12-14). On the other hand, despite the increasing incidence of pre hypertension and its association with CVD, scarce studies were conducted about the association between general and abdominal obesity and pre-hypertension. Moreover, the predictive power of different anthropometric indices also depends on the ethnic origin of the studied population. Therefore, defining population-specific anthropometric indices are necessary to determine subjects at risk for hypertension (15-17).

In order for early detection of at risk people and also planning of preventive strategies, it is important to identify strong predictors of hypertension and prehypertension in each population. Therefore, for the first time in the Iranian population, the power of different indices of general and central obesity in prediction of incident prehypertension and hypertension were assessed.

2. Methods

The data of this cross-sectional study were gained from the Azar cohort study, which is established in Shabestar in East Azerbaijan province (north west of Iran) and also it is a part of a large Persian cohort study (The prospective epidemiological research studies of the Iranian Adults). This study was launched at October 2014 and conducted in 3 phases of pilot, enrolment, and follow-up. Written informed consent was obtained from all participants. This prospective study was approved by Ethics Committee of Tabriz University of Medical Sciences (tbzmed.rec.1393.205).

2.1. Subjects and Data

All eligible individuals 35 - 70 years of age in the region of Shabestar are invited to participate in the study and those who signed the consent form are included (totally 10,137 subjects). Those included were inhabitants in Shabester for at least 9 months. The participants with severe psychiatric or physical illness were excluded from the study. From October 2014 to June 2016, out of 10,788 subjects who were invited, 10,137 responded. The response rate was 94%.

In the Azar cohort study, firstly the lists of all subjects age 35 - 70 years were obtained from the health centers of Shabestar region. From small cities and villages, approximately all eligible individuals 35 - 70 years were invited. In other cities, more than 60% of eligible subjects were invited. In January 2017, the enrollment phase has been finished and 15,000 subjects were recruited. For invitation, 1 week before the day of visit, people were contacted by telephone and conditions of the cohort study were explained. In addition, if the person agreed to participate in the study, the date of visit day, were given to him/her.

2.2. Anthropometric Measurements

Mounted tape was used for measuring the height to the nearest 1 mm and Seca scale was used for recording weight to the nearest 0.1 kg, according to standard protocols. Weight was measured by Seca scale. Every day, suitable standard 10 kg weights was used for calibration of weighing scales. Body mass index was calculated by dividing weight (in kilogram) by the square of height (in meter). BMI was classified according to the WHO (18) categories: underweight (BMI $<$ 18.5 kg/m^2), normal (BMI 18.5 - 24.9 kg/m^2), overweight (BMI 25 - 29.9 kg/m^2), and obesity (BMI $\geq$ 30 kg/m^2). WC and hip circumference of subjects are measured according to NIH (National Institute of Health) guidelines. Waist to hip ratio (WHR) and waist to height ratio (WHtR) were calculated by dividing waist to hip and height, respectively. In men, WC was $\geq$ 102 cm and WHR $\geq$ 0.9 cm, in women WC was $\geq$ 88 cm and WHR $\geq$ 0.85 cm, and in both genders, WHtR $\geq$ 0.5 were considered as a risk factor.

2.3. Blood Pressure Definition

Blood pressure was measured twice with 10 minutes apart from both upper extremities separately, by a trained nurse using a mercury sphygmomanometer (Riester, Germany). It was calibrated by mercury sphygmomanometers.

The mean of measurements were recorded as the blood pressure. Prehypertension was defined as having either a SBP of 120 to 139 mmHg and/or DBP of 80 to 89 mmHg, according to JNC7, in persons who were not on antihypertensive medication (19). Subjects with SBP $\geq$ 140 and DBP $\geq\geq$ 90 or use of antihypertensive drug with a history of hypertension were considered as patients with hypertension.

To reduce individual errors in anthropometric and blood pressure measurements sections, in each section, only 1 trained person assessed anthropometric and blood pressure measurements. We have an epidemiologist who checked all filled questionnaires as well as anthropometric and blood pressure measurements. Moreover, another one monitored the work of the epidemiologist.

2.4. Statistical Analysis

Statistical package for the social sciences (SPSS, version 11.5, Chicago, IL) was used to analyze data. Descriptive statistics were obtained for all study variables and reported as mean ± SD and also number (percent) where applicable. The normality of data was assessed by the Kolmogrov-Smirnove test. All data had normal distribution.

We used logistic regression analysis for estimating crude and adjusted odds ratios (OR) and their corresponding 95% confidence intervals (95%CI). On the basis of BMI classification, 13 women and 47 men were under weight that were excluded in logistic regression analysis. A P value of less than 0.05 was considered statistically significant.

3. Results

The baseline characteristics of study subjects stratified by sex were presented in Table 1. The mean age of the participants was 49.32 ± 9.15 years. The mean BMI (kg/m^2), WC (cm), WHR, and WHtR were 28.75 ± 4.83, 94.69 ± 11.23, 0.90 ± 0.07, and 0.58 ± 0.07, respectively. About 36.6% of participants were obese and 23.3% of them had hypertension.

Table 2 presents the percent of patients with different blood pressure status in different anthropometric subclasses. As can be seen, respectively 32.5%, 32.6%, 28.6%, and 25.6% of subjects with obesity, WC ≥ 102 cm in men and >88 cm in women, WHR ≥ 0.9 (men) and 0.85 (women) and WHtR > 0.5, had hypertension. The prevalence of hypertension in obese women, women with WC ≥ 88cm, WHR ≥ 0.85, and WHtR ≥ 0.5 were more than their men counterparts.

The association between different anthropometric indices and prehypertention and hypertension was presented in Table 3. There is a significant association between prehypertension and hypertension with all included anthropometric indices in both genders (All P < 0.001).

In men, in an unadjusted model, BMI had the highest OR with prehypertension and WHtR had the highest OR with hypertension. However, after adjusting for age, BMI had the highest association with both hypertension and prehypertension. Moreover, obesity increased risk of prehypertension and hypertension by 3.13 (95%CI: 2.48 - 3.94) and 4.06 (95%CI: 3.23 - 5.10). After adjustment for age, the observed association were increased (OR = 3.43; 95% CI: 2.70 - 4.35, OR = 4.74; 95%, CI = 3.71 - 6.07). After WHtR, BMI, WHR, and WC, respectively had the highest OR for hypertension.

In women, BMI and WHtR had the highest associations with prehypertension and hypertension in both adjusted and unadjusted models. In women with WHtR > 0.5 cm, the risk of hypertension increased by 6.27 (95%CI: 4.39 - 8.95) times. However, this association was decreased after adjustment for age.

After adjustment for age, the strong predictor of prehypertension and hypertension were BMI and WHtR in men

Table 1. Baseline Characteristics of Participants[a]

Variable	Men	Women	Total
Age, y	49.92 ± 9.12	48.83 ± 9.14	49.32 ± 9.15
Weight, kg	79.58 ± 13.50	72.98 ± 12.83	75.95 ± 13.54
Height, cm	170.51 ± 6.72	72.98 ± 12.83	162.63 ± 9.70
Waist, cm	96.09 ± 11.22	93.55 ± 11.11	94.69 ± 11.23
BMI, kg/m^2	27.35 ± 4.27	29.90 ± 4.96	28.75 ± 4.83
WHR	0.93 ± 0.07	0.87 ± 0.07	0.90 ± 0.07
WHtR	0.56 ± 0.06	0.59 ± 0.07	0.58 ± 0.07
SBP, mm/Hg	112.34 ± 16.59	113.85 ± 17.62	113.17 ± 17.18
DBP, mm/Hg	73.22 ± 9.32	73.29 ± 10.07	73.26 ± 9.74
BMI, kg/m^2			
Underweight	48 (1.1)	13 (0.2)	61 (0.6)
Normal (18.5 - 24.9)	1292 (28.4)	835 (15)	2127 (21)
Overweight (25 - 29.9)	2081 (45.78)	2152 (38.5)	4233 (41.8)
Obese, (≥ 30)	1127 (24.7)	2576 (46.1)	3703 (36.6)
WC, cm			
< 102 in men/ < 88 in women	3275 (72)	1734 (31.1)	5009 (49.5)
≥ 102 in men/ > 88 in women	127 (28)	3834(68.8)	51.5 (50.5)
WHR			
< 0.9 in men/ < 85 in women	1357 (29.8)	2033 (36.4)	3390 (33.4)
≥ 0.9 in men/ > 85 in women	3190 (70)	3542 (63.4)	6732 (66.4)
WHtR			
< 0.5	774 (17)	469 (8.4)	1243 (12.3)
≥ 0.5	3773 (82.9)	5107 (91.5)	8880 (87.6)
Hypertensionsystolic/dia mmHg			
Normal (< 120 and < 80)	2968 (65.2)	3117 (55.8)	6085 (60)
Prehypertension (120 - 139 or 80 - 89)	731 (16.1)	919 (16.5)	1650 (16.3)
Hypertension, ≥ 140 or ≥ 90)	831 (18.2)	1530 (27.4)	2361 (23.3)

Abbreviations: BMI, body mass index; DPB, diastolic blood pressure; N, number; SBP, systolic blood pressure; WC, waist circumference; WHR, waist to hip ratio; WHtR, waist to height ratio.
[a]Values are expressed as No. (%).

Table 2. The Percent of Patients with Different Blood Pressure Status in Different Anthropometric Subclass[a]

Variables	Men			Women			Total		
	Normal	Prehypertenstion (120 - 139 or 80 - 89)	Hypertension ($\geq$ 140 or $\geq$ 90)	Normal (< 120 and< 80)	Prehypertension (120 - 139 or 80 - 89)	Hypertension ($\geq$ 140 or $\geq$ 90)	Normal (< 120 and < 80)	Prehypertenstion (120 - 139 or 80 - 89)	Hypertension ($\geq$ 140 or $\geq$ 90)
Body mass index, kg/m^2									
Normal (18.5 - 24.9)	1008 (78.1)	139 (10.8)	133 (10.3)	611 (73.3)	90 (10.8)	130 (15.6)	16.19 (76.2)	229 (10.8)	263 (12.4)
Over-weight (25 - 29.9)	1351 (64.2)	338 (16.2)	385 (18.5)	1330 (61.8)	318 (14.8)	501 (23.3)	2681 (63.3)	656 (15.5)	886 (20.9)
Obese ($\geq$ 30)	572 (50.7)	247 (21.9)	307 (27.2)	1159 (45)	510(19.8)	898 (34.8)	1731 (46.7)	757 (20.4)	1205 (32.5)
Waist circumference (WC)									
< 102 in men/ < 88 in women	2342 (71.5)	496 (14.3)	448 (13.7)	1289 (74.3)	196 (11.3)	245 (14.1)	363 (72.5)	665 (13.3)	693 (13.8)
$\geq$ 102 in men/ $\geq$ 88 in women	625 (49.1)	261 (20.5)	383 (30.11)	1827 (47.5)	722 (18.8)	12.84 (33.4)	2452 (47.9)	983 (19.2)	1667 (32.6)
Waist to hip ratio (WHR)									
< 0.9 in men and < 0.85 in women	1077 (79.3)	152 (11.2)	120 (8.8)	1465 (72.1)	245 (12.1)	313 (15.4)	2542 (75)	397 (11.7)	433 (12.8)
$\geq$ 0.9 in men and $\geq$ 0.85 in women	1890 (59.2)	578 (18.1)	711 (22.3)	1216 (46.6)	673 (19.1)	1216 (34.3)	3540 (52.6)	1251 (18.6)	1927 (28.6)
Waist-to-height ratio (WHTR)									
< 0.5	649 (83.9)	65 (8.41)	53 (6.8)	389 (82.9)	44 (9.4)	34 (7.2)	1038 (83.5)	109 (8.8)	87 (7)
$\geq$ 0.5	2318 (61.4)	665 (17.6)	778 (20.6)	2726 (53.4)	874 (17.1)	1495 (29.3)	5044 (56.8)	1539 (17.3)	2273 (25.6)

[a] Normal: systolic blood pressure < 120 mmHg and diastolic blood pressure < 80 mmHg; Prehypertension: systolic blood pressure < 120 - 139 mmHg and diastolic blood pressure < 80 - 89 mmHg; hypertension, systolic blood pressure > 140 mmHg and diastolic blood pressure $\geq$ 90 mmHg.

and women, respectively.

4. Discussion

This paper presents the cross sectional analysis of the 1st phase of a comprehensive community based survey of Azar cohort conducted in North West Iran. According to the results, in the large sample of Azar cohort, the prevalence of prehypertension and hypertension were 16.3% and 23.3%, respectively. The prevalence of hypertension in East Azerbaijan was reported to be 20.47% in 2007 (20), which indicates that prehypertension/hypertension rates in adults are rising at an alarming rate. Previous studies in USA (21), China (22), and Egypt (23) reported higher prevalence of prehypertension and hypertension. Moreover, in the present study, the prevalence of hypertension in subjects with BMI $\geq$ 30 kg/m^2, WC $\geq$ 102 cm in men and $\geq$ 88 cm in women, WHR $\geq$ 0.9 (men) and 0.85 (women), and WHtR $\geq$ 0.5 were 32.5%, 32.6%, 28.6%, and 25.6%, respectively, which was lower than previous reports from other countries. In the Indian population, the prevalence of hypertension was reported to be 40.8% (BMI > 27.6 kg/m^2), 47.2% (WC > 98.1 cm), 44.7% (WHR > 0.98), and 45.9% (WHtR > 0.59) (24). The prevalence of prehypertension in Vietnamese adults was reported to be 40.7% (men) and 38.2% (women) and the prevalence of hypertension was 50% (men) and 34.9% (women). A wide range of prevalence of hypertension in various countries may be due to the differences in the social and cultural differences, different behavioral and dietary lifestyles, the age span, as well as the methodology used.

The results of the present study further support the idea of association between anthropometric indices and hypertension. In a large study of the Chinese population (25), BMI and WC were associated with hypertension. In the mentioned study, other anthropometric indices such as WHtR and WHR as well as the association between prehypertension and anthropometric indices were not studied.

Table 3. Logistic Regression of the Association Between Prehypertension and Hypertension and Anthropometric Indices in Iranian Adults[a]

Variables	Pre-Hypertension		Hypertension	
	Unadjusted OR[b]	Adjusted OR[c]	Unadjusted OR[b]	Adjusted OR[c]
Men				
BMI, kg/m²				
18.5 - 24.99	1	1	1	1
25 - 29.99	1.81 (1.46, 2.24)	1.90 (1.52, 2.36)	2.16 (1.74, 2.67)	2.54 (1.88, 3.42)
≥ 30	3.13 (2.48, 3.94)	3.43 (2.70, 4.35)	4.06 (3.23, 5.10)	4.74 (3.71, 6.07)
WC, cm				
< 102	1	1	1	1
≥ 102	2.08 (1.75, 2.48)	2.01 (1.68, 2.40)	3.20 (2.72, 3.76)	2.93 (2.46, 3.49)
WHR				
< 0.9	1	1	1	1
≥ 0.9	2.16 (1.78, 2.63)	1.94 (1.59, 2.36)	3.37 (2.74, 4.15)	2.76 (2.22, 3.43)
WHtR				
< 0.5	1	1	1	1
≥ 0.5	2.86 (2.18, 3.74)	2.64 (2.01, 3.47)	4.11 (3.07, 5.50)	3.63 (2.68, 4.92)
Women				
BMI, kg/m²				
18.5 - 24.99	1	1	1	1
25 - 29.99	1.62 (1.26, 2.09)	1.61 (1.25, 2.09)	1.77 (1.42, 2.19)	1.86 (1.46, 2.37)
≥ 30	2.98 (2.33, 3.81)	2.49 (2.01, 3.07)	3.44 (2.95, 4.48)	3.74 (2.96, 4.74)
WC, cm				
< 88	1	1	1	1
≥ 88	2.59 (2.18, 3.09)	2.32 (1.95, 2.77)	3.69 (3.16, 4.31)	2.87 (2. 43, 3.41)
WHR				
< 0.85	1	1	1	1
≥ 0.85	2.43 (2.07, 2.86)	2.00 (1.69, 2.37)	3.44 (2.99, 3.97)	2.09 (1.79, 2.45)
WHtR				
< 0.5	1	1	1	1
≥ 0.5	2.83 (2.05, 3.90)	2.36 (1.70, 3.26)	6.27 (4.39, 8.95)	4.26 (2.91, 6.22)

Abbreviations: OR, odds ratio; WC, waist circumference; WHR, waist to hip ratio; WHtR, waist to height ratio.
[a] Prehypertension: systolic blood pressure < 120 - 139 mmHg and diastolic blood pressure < 80 - 89 mmHg; hypertension: systolic blood pressure > 140 mmHg and diastolic blood pressure ≥ 90 mmHg.
[b] 95%CI: confidence interval.
[c] Adjusted for age.

In a church-base study on the Nigerian population, BMI and WHtR were significantly associated with hypertension (26). In addition, they found that BMI and WC had more predictor power for pre hypertention (26).

Kaur et al. in industrial men showed that both hypertension and prehypertension were significantly associated with BMI, WC, WHR, and WHtR (24). Multiple mechanisms, including the reninangiotensin-aldosterone system activation, increased sympathetic nervous system (SNS) activity and insulin resistance, increased renal sodium reabsorption, impaired pressure natriuresis, and volume expansion were involved in obesity-related HTN association (27).

Although the association between obesity, pre hypertension, and hypertension were reported in previous studies from Iran and other countries, the power of each an-

thropometric indices in predicting prehypertension and hypertension should be determined in each population. As far we know, no study on the Iranian population has been performed to answer the question, "which of the anthropometric indices were best predictor of prehypertension and hypertension". The results of the present study showed that WHtR is correlated with a higher OR than BMI for hypertension, in contrast, BMI is associated with a higher OR for prehypertension. In line with our study, Deng et al. in a study on the Chinese population showed that BMI had higher association with prehypertension, while WC had higher a OR than BMI for hypertension (25). The strong correlation was observed between BMI and prehypertension and hypertension in the Chinese population (28). Moreover, according to the results of the DECODA study, both waist-to-height ratios and BMI were reported as a strong predictor of hypertension in Asians (29). In contrast, Ma et al. reported that WC were more predicative than BMI and WHtR for pre hypertention (30). In Australian adults, WHR has been suggested as the most useful index of obesity to recognize individuals with cardiovascular disease risk factors (24). The discrepancies between the different studies results may be ascribed to the differences in the study populations. It seems that WHtR along with BMI are a useful index for recognizing prehypertension and hypertension, rather than using only 1 of these measures for the Iranian population. WHtR and BMI are the convenient index for use in the population, they have only one cut-off for both sex, which is easy to memorize and consumer-friendly.

As reported by previous studies, age had modifying effects on association between different anthropometric indices and hypertension (25, 31). These observations may be due to increasing the central obesity and declining in height with increasing in age.

The strengths of the present study were using a large population based sample and a prospective cohort design, duplicate measuring of anthropometric indices, and blood pressure. However, considering insufficient covariates included in the present study, these results should be interpreted with caution. Other covariate, rather than age, may influence the association between anthropometric indices and hypertension such as depression, anxiety, dietary factors, and physical activity pattern. Moreover, due to the cross sectional analysis of data, causal relations may not be established.

In conclusion, the results of this large population-based study showed that all anthropometric indices were associated with prehypertension and hypertension both in men and women. Moreover, BMI is the best predictor of prehypertension and hypertension in men. In addition, WHtR combined with BMI were the best predictor of prehypertension and hypertension in women. These findings may have important implications in using the most useful screening index for predicting hypertension in Iranian adults and also using WHtR for early detection of prehypertension (before hypertension will be existed).

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Footnotes

Authors' Contribution: Study concept and design: Mohammadhossein Somi, Elnaz Faramarzi; acquisition of data: Mohammadhossein Somi; analysis and interpretation of data: Elnaz Faramarzi; drafting of the manuscript: Elnaz Faramarzi, Zeinab Nikniaz; critical revision of the manuscript for important intellectual content: Ali Fakhari, Zeinab Nikniaz; statistical analysis: Mohamad Asgari Jafarabadi; administrative, technical, and material support: Alireza Ostadrahimi; study supervision: Alireza Ostadrahimi.

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