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ORIGINAL ARTICLE

Role of Obesity Variables in Detecting Hypertension in an Iranian Population

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Abstract
Introduction As the high incidence of hypertension has been in conjunction with dramatic increase in the prevalence of obesity, many studies have suggested obesity as its underlying cause in diverse race and ethnic groups.
Aim The present study was designed to quantify the relationship between obesity variables and hypertension in Iranian population. A ROC curve analysis was also used to determine an optimal BMI cutoff for obesity with the aim of representing elevated incidence of hypertension in this population.
Methods The study population comprised of apparently healthy men and women who participated in the Iranian Multicentric Osteoporosis Studies (IMOS), a multi-centric cross-sectional study carried out in urban areas of five great cities (Tehran, Tabriz, Mashhad, Shiraz and Bushehr). The anthropometric (weight, height, waist and hip circumferences) and blood pressure measures were reported in some 5724 subjects. The influence of these factors on systolic and diastolic blood pressure was assessed based on a list-wise method.
Results There was a significant difference in the studied subjects anthropometric (weight classes (BMI), WC and HC, and WHR) and blood pressure variables; age, gender and weight, however, were the only factors significantly influencing SBP and DBP. Furthermore, BMI showed a significant impact on the overall risk of developing hypertension.
Conclusion General obesity rather than abdominal obesity is directly linked with higher blood pressure levels in Iranian population.

Keywords Obesity · Abdominal obesity · Blood pressure · Hypertension · Systolic blood pressure · Diastolic blood pressure · Waist circumference · Waist to hip ratio

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1 Introduction

Nowadays, hypertension, an accelerator of cardiovascular events and renal disorders, has become a global public health concern because of its high prevalence [1, 2]. In view of the fact that its high incidence has been in conjunction with the dramatic increase in the prevalence of obesity, many studies have suggested obesity as its underlying cause in diverse race and ethnic groups [3–5].

Although the physiopathology of obesity-related hypertension is not fully understood, renal malfunction and insulin resistance are considered as the main causes contributing to the condition [6, 7]. Controversial reports, however, have pointed out the role of fat-derived adipokines, including leptin and adiponectin, in linking body fat and elevated blood pressure [8, 9].

While body mass index (BMI) is commonly used in many epidemiologic studies on obesity, the marker is reported incapable in differentiating body fat and lean body mass in many studies; body fat distribution, for that reason, is referred to be a more critical correlate of the complications found among overweight and obese individuals compared to excess body fatness per se [10–13].

In this regard, the use of waist circumference (WC) as a marker of abdominal fat accumulation has been proposed in many studies; many of which have shown an association between WC and hypertension, suggesting WC to be a better predictor for detecting hypertensive cases [14–16]. Some others, however, have reported waist circumference to hip ratio (WHR) as a more accurate screening tool [17, 18].

In Iran, studies with a good sample size regarding the effects of the indicators of fat distribution (WC, HC and WHR) on blood pressure are still scarce. Thus, the aim of the present study was to investigate whether these indicators, in addition to BMI, have a relationship with the risk of hypertension in Iranian population. A ROC curve analysis was also used to determine an optimal BMI cutoff for obesity with the aim of representing elevated incidence of hypertension in this population.

2 Materials and Methods

2.1 Case Selection

The study population comprised of apparently healthy men and women who participated in the Iranian Multi-centric Osteoporosis Studies (IMOS), a multi-centric cross-sectional study carried out in urban areas of five great cities (Tehran, Tabriz, Mashhad, Shiraz and Bushehr) in late winter (February–March).

Details on the survey design and methods have been reported previously [19]. Briefly, the IMOS used a random cluster sampling design to draw five provincially representative, independent samples of healthy adults excluding those taking medications that could modify bone metabolism, those with hepatic or renal disorders, metabolic bone disease, hypercortisolism, malabsorption, sterility, oligomenorrhea, type I diabetes, malignancy, and immobility for more than 1 week as well as the pregnant and lactating women. The Research Ethics Committee of the Endocrine and Metabolism Research Center (EMRC) approved the protocol of this study.

2.2 Anthropometric Measurements

Approximately 5724 subjects met the inclusion criteria and gave their written consent. The check-up included anthropometric and blood pressure measures. Anthropometric measurements including weight, height, waist and hip circumferences were obtained with light clothing and without shoes by trained technicians following international guidelines [20]. Each anthropometric measurement was done by a similar instrument, and with the same technique. Quality control for all measurements was monitored regularly.

The height (to the nearest 0.1 cm) and the weight (to the nearest 0.1 kg) were measured using a wall-mounted stadiometer (Seca) and a mobile digital scale (Seca, Hamburg, Germany), respectively. The BMI was calculated as the body weight divided by the height squared (kg/m^2). The waist and hip circumference were measured using a non-elastic flexible anthropometric tape (to the nearest 0.1 cm) in the standing position. The tape was applied horizontally midway between the lowest rib margin and the iliac crest for WC and the widest point over the buttocks for HC measurements. The waist to hip ratio (WHR) was calculated as WC was divided by the HC [20–22].

Blood pressure (BP) was measured on the dominant arm by trained and standardized nurses using a mercury sphygmomanometer (Reishter, Germany; provided with an appropriate size cuff according to the arm circumference of the subject) in the sitting position after a 10-min rest period. The subjects were asked not to smoke or consume caffeine during the 30 min preceding the measurement. Systolic BP (SBP) was defined by the onset of the first Korotkoff sound, and diastolic BP (DBP) was indicated by the fifth Korotkoff sound (disappearance of Korotkoff sound) [20, 21, 23].

The individuals were then categorized according to their baseline BMI values (underweight <18.5, normal weight 18.5–25, overweight 25–29.9, and obese ≥30 kg/m^2) [22]. The quartiles of WC, HC and WHR were considered to define each class.

Blood pressure values were classified according to the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure as normal (<120/80 mmHg), Pre HTN (120–139/80–89 mmHg), and Hypertension (≥140/90 mmHg) [Stage 1: 140–159/90–99 mmHg, Stage 2: ≥160/100 mmHg] [23].

2.3 Statistical Analysis

Data were entered to Microsoft Access Databank, checked, and cleaned before analysis. Data analysis was performed using SPSS software version 13 and analyzed based on a pair-wise approach. Means ± SD or medians were used to express standard descriptive statistics. Categorical variables were expressed as percentages. Differences among means were investigated by analysis of variance (ANOVA) and post-hoc comparisons. Comparison of percentages of the categorized variables was made using the Pearson chi-square test.

Pearson's coefficient was calculated for the correlation. Analysis of covariance (ANCOVA) was performed to describe the influence of WC, HC and WHR, in addition to BMI on the SBP and DBP endpoint variables. The significance level was chosen as 0.05.

ROC curves were used to evaluate an optimal BMI and WC cutoff for predicting hypertension.

3 Results

A total of 5724 individuals with the mean age of 42.64 ± 13.85 years were studied; from among them 2396 (43%) were male. The demographic and anthropometric characteristics of the study population are presented in Table 1. From among the studied cases 820 (26.8%) had normal blood pressure, 1441 (47.1%) had pre hypertension, 546 (17.6%) had stage 1 hypertension, and 274 (8.8%) were suffering from stage 2 hypertension.

Considering the BMI categories, 164 (3.2%) were underweight, 1990 (38.6%) were normal weight, 1986 (38.5%) were overweight, and 1014 (19.7%) were obese. There was a significant association between weight class and gender (P-value < 0.001). For both WC and WHR, significant differences were observed among genders (all P values < 0.001).

The description of WC, HC and WHR values, according to weight classes, is shown in Table 1. Some 18.5% (204/805) of the adults who presented with hypertension had normal weights.

Comparing the individuals of each of the three blood pressure groups, there was a significant difference in their anthropometric and blood pressure variables (Tables 2, 3).

There was a significant association between hypertension and weight classes, WC and HC, and WHR (P < 0.001 for both sexes) (Table 3). BMI changes were significantly associated with an increased risk of developing hypertension (P < 0.001). There was a trend toward increased chance of developing HTN across the WC, HC and WHR quartiles ($P < 0.001$), the lowest values were found in quartile 1.

The result of the linear regression analysis of SBP and DBP values in relation to BMI values showed the strong influence of BMI on SBP and DBP. Regression β coefficients showed that for each category change in BMI, SBP would elevate up to +0.981 mmHg, whereas DBP may rise to +0.173 mmHg (Table 4). Age, gender and weight were the only factors significantly influencing SBP and DBP values; WHR, additionally, had a strong impact on SBP values. Furthermore, we detected a significant but negative effect of height on SBP.

In the male gender, BMI (general obesity) and WC (central obesity) were associated with −0.406 (P-value = 0.700) and 1.382 (P-value = 0.002) increase in SBP as well as 0.203 (P-value = 0.737) and 0.171 (P-value = 0.512) increase in DBP; except for the effect of WC on SBP, the others were not statistically significant. In contrast among females, BMI (general obesity) and WC (central obesity) were associated with 1.803 (P-value = 0.089) and 0.623 (P-value = 0.016) increase in SBP as well as 2.397 (P-value < 0.001) and 0.504 (P-value = 0.002) increase in DBP.

The prevalence rates of hypertension in the overall group were 799 (26.11%) and were significantly different between the two genders, with 392 (49.1%) in females and 407 (50.9%) in males (P < 0.001). As for the overweight and obese group, the prevalence rate of the conditions was 320 (39.7%) and 272 (33.8%) respectively. When compared with the normal weight group, the chance of developing hypertension in overweight group and obesity group were 1.559 and 3.022 respectively. WC, HC and WHR did not influence the risk of hypertension (Table 5).

A BMI of 28.8 kg/m^2 for women and of 24.2 kg/m^2 for men is suggested as the most appropriate cut-off levels to detect hypertension in the studied population (Fig. 1).

Table 1 Demographic data based on weight class

	Total (mean ± SD)	Underweight (mean ± SD)	Normal weight (mean ± SD)	Overweight (mean ± SD)	Obese (mean ± SD)	P-value
Age (years)	42.64 ± 13.85	35.29 ± 15.45	39.70 ± 14.76	45.01 ± 12.88	45.76 ± 11.66	<0.001
Height (cm)	163.88 ± 9.75	168.35 ± 10.10	165.90 ± 9.51	163.68 ± 9.60	159.67 ± 8.99	<0.001
Weight (kg)	70.36 ± 13.15	49.63 ± 6.61	61.70 ± 8.35	73.37 ± 8.97	84.88 ± 11.50	<0.001
WC (cm)	90.94 ± 12.35	70.76 ± 7.64	82.52 ± 9.03	93.20 ± 8.61	103.10 ± 10.08	<0.001
HC (cm)	104.42 ± 10.47	87.55 ± 8.35	97.59 ± 6.77	105.66 ± 7.99	115.38 ± 8.42	<0.001
Sys BP (mmHg)	120.72 ± 19.08	108.86 ± 14.91	116.67 ± 18.39	121.46 ± 18.04	127.56 ± 19.88	<0.001
Dia BP (mmHg)	79.07 ± 10.90	73.35 ± 8.98	76.77 ± 10.05	79.35 ± 10.61	82.95 ± 11.70	<0.001
WHR	0.87 ± 0.08	0.82 ± 0.16	0.85 ± 0.08	0.88 ± 0.08	0.90 ± 0.09	<0.001

BMI values: underweight <18.5, normal weight 18.5–25, overweight 25–29.9, and obese ≥30 kg/m^2

Table 2 Demographic data based on HTN classification

	Normal (mean ± SD)	Pre HTN (mean ± SD)	HTN (mean ± SD)	P-value
Age (years)	36.94 ± 12.28	40.68 ± 13.29	51.22 ± 12.85	<0.001
Height (cm)	163.33 ± 9.34	164.79 ± 9.80	163.19 ± 9.91	<0.001
Weight (kg)	66.94 ± 13.26	72.04 ± 12.51	75.14 ± 13.06	<0.001
WC (cm)	86.54 ± 11.91	91.90 ± 11.62	97.17 ± 11.68	<0.001
HC (cm)	102.27 ± 10.52	104.70 ± 9.62	106.88 ± 9.30	<0.001
Sys BP (mmHg)	102.11 ± 9.40	118.57 ± 9.15	143.27 ± 16.61	<0.001
Dia BP (mmHg)	67.35 ± 5.08	78.98 ± 4.59	90.99 ± 10.36	<0.001
BMI (kg/m^2)	25.11 ± 4.62	26.60 ± 4.52	28.28 ± 4.85	<0.001
WHR	0.85 ± 0.08	0.88 ± 0.08	0.91 ± 0.07	<0.001

Blood pressure values: normal <120/80, pre HTN 120–139/80–89, and hypertension ≥140/90 mmHg

Table 3 Demographic data based on HTN classification

	Normal N (%)	Pre HTN N (%)	HTN N (%)	Correlation
Gender				
Male	285 (20.5)	699 (50.3)	407 (29.2)	–**
Female	535 (32.1)	742 (44.4)	392 (23.5)	
BMI cat[a]				
Underweight	38 (48.1)	32 (40.5)	9 (11.4)	
Normal weight	379 (34.4)	518 (47.0)	204 (18.5)	0.226**
Over weight	294 (24.1)	608 (49.8)	320 (26.2)	
Obese	98 (14.7)	297 (44.5)	272 (40.8)	
WC cat				
<P25	326 (43.4)	337 (44.9)	88 (11.7)	0.308**
P25–P50	196 (27.8)	363 (51.3)	148 (20.9)	
P50–P75	178 (23.4)	374 (49.1)	209 (27.5)	
>P75	103 (13)	346 (43.5)	346 (43.5)	
HC cat				
<P25	238 (29.6)	288 (20.3)	114 (14.4)	0.172**
P25–P50	226 (28.1)	357 (25.1)	179 (22.6)	
P50–P75	176 (21.9)	374 (26.3)	208 (26.3)	
>P75	163 (20.3)	401 (28.2)	291 (36.7)	
WHR cat				
<P25	334 (44.5)	335 (44.6)	81 (10.9)	0.296**
P25–P50	189 (25.3)	387 (51.8)	171 (22.9)	
P50–P75	159 (21.5)	358 (48.4)	223 (30.1)	
>P75	111 (14.8)	328 (43.7)	311 (41.5)	

Blood pressure values: normal <120/80, pre HTN 120–139/80–89, and hypertension ≥140/90 mmHg

** Correlation is significant at the 0.01 level (2-tailed)

[a] BMI values: underweight <18.5, normal weight 18.5–25, overweight 25–29.9, and obese ≥30 kg/m^2

4 Discussion

Obesity is a global health problem associated with social and psychological problems along with various cardiovascular risk factors such as elevated blood pressure, dyslipidemia, insulin resistance and type-2 diabetes [5, 24–28].

While BMI had long been considered as the most accurate diagnostic indicator of obesity in clinical practice particularly in predicting cardiovascular risk factors, more recent studies have shown a high prevalence of metabolic abnormalities in normal-weight individuals [10, 24, 29, 30]. Many of them have reported a higher risk of developing cardiovascular disease, hypertension, hyperglycemia and dyslipidemia among normal weight individuals with elevated adiposity [10, 31–33].

It could be therefore concluded that not only the amount of body fat mass but also the distribution of this fat determines the risk of health conditions such as hypertension associated with obesity [10]. Certain studies hence have considered a marker of body fat distribution such as WC along with higher BMI as the most accurate tool in estimating cardiovascular and hypertension risk by anthropometric variables among men and women in all race/ethnic groups and in most age groups [34–37]. This biologic paradigm underscored the importance of the BMI classification in this issue.

As a result, many studies reported a significant influence of waist or waist to height ratio on hypertension risk regardless of the subject's weight class [38]. Certain others showed the positive association between WC and high BP, adding that hip and thigh circumferences to be negatively associated with hypertension risk [39–41]. Others, however, reported that high WHR in the presence of normal BMI is associated with increased DBP in women [14, 42].

As expected, in our population, the prevalence of hypertension increased with higher weight class in both genders. The present study similarly revealed that hypertension can be detected even in normal weight individuals (18.5%); it, however, reported no link between abdominal obesity and the higher prevalence of hypertension, indicating that BMI is the most accurate predictor of hypertension.

Corroborating with previous studies assessing the effect of weight on blood pressure values, SBP is most often affected, an association that has been observed as early as

Table 4 The impact of various demographic variables on systolic and diastolic blood pressure

	Dia BP		Sys BP	
	B coefficient	95% CI	B coefficient	95% CI
Age	0.194**	0.163 to 0.226	0.546**	0.495 to 0.598
Gender				
Male	3.287**	2.144 to 4.431	5.697**	3.830 to 7.565
Female	0	–		
Weight	0.083*	0.007 to 0.159	0.294**	0.173 to 0.45
Height	−0.044	−0.123 to 0.035	−0.254**	−0.382 to −0.127
BMI cat[a]	0.944	−0.149 to 2.037	0.113	−1.656 to 1.881
WC cat	0.188	−0.625 to 1.002	−0.480	−1.809 to 0.849
HC cat	0.316	−0.331 to 0.963	−0.201	−1.259 to 0.856
WHR cat	0.278	−0.322 to 0.878	1.292*	0.312 to 2.272

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

[a] BMI values: underweight <18.5, normal weight 18.5–25, overweight 25–29.9, and obese ≥30 kg/m^2

Table 5 The logistic regression analysis regarding the impact of various demographic variables on the development of hypertension

	HTN		
	OR	P-value	95% CI
Age	1.068	<0.001**	1.060–1.076
Sex	0.557	<0.001**	0.453–0.684
BMI	1.085	<0.001**	1.051–1.121
WC	1.038	0.276	0.971–1.109
HC	0.975	0.407	0.917–1.036
WHR	0.044	0.391	0.000–55.753

** Correlation is significant at the 0.01 level (2-tailed)

the first year of life [9, 36, 43]. While previous studies had reported no consistent association between being overweight and high DBP; the present study revealed the strong impact of weight but not weight classes on this variable [6, 9].

Although many studies have reported a positive and continuous relation of abdominal obesity (WC) accumulation with systolic BP, the present study was not able to point out such as relation [15, 44]. Conversely, the results of the present study regarding the absence of any relation between WC and DBP was in consistence with previous studies [45, 46]. The present study, however, reported that WC and abdominal obesity are strong factors influencing SBP in each gender, whereas BMI and general obesity are strongly correlated with DBP only in women.

Colin-Ramirez et al. demonstrated that WC was the most important adiposity indicator associated with the presence of systolic hypertension [6]. Certain studies, on the other hand reported WHR as the preferred measure of obesity in predicting the hypertension risk, adding that WHR offers additional valuable predictive information beyond BMI and WC on hypertension [14, 36, 47].

The main result of the present study is that weight rather than weight class is related to the risk of hypertension. It, however, suggests a strong positive association between BMI and the incidence of hypertension in each gender, adding that an optimal BMI cutoff to define obesity in Iranian adults is about 28.89 kg/m^2. This cutoff is much higher than that reported in Chinese and Indians population, showing a BMI cutoff of 22–24 kg/m^2 to be associated with an increase in the prevalence of hypertension [21, 48, 49]. The higher total body fat and the greater amount of abdominal and visceral fat as well the genetics, socioeconomic status, cultural factors, food habits, physical activity levels, and lifestyles differences among different ethnicities is the main reason contributing to the higher optimal BMI cutoffs in this population [50, 51].

5 Study Limitations

The present study was an observational study in which blood pressure was measured in a single session by trained and standardized team of nurses through the auscultatory method; some subjects, therefore, may have been misclassified as having borderline high blood pressure.

Additionally, individuals recruited in this study were assumed to be healthy based on their self-reported history, indicating that they were not examined for factors influencing the blood pressure such as renal function during the study period. Moreover, the impact of other factors such as eating habits and physical activity along with certain biochemical measurements including lipid profile on the findings of this study was not assessed.

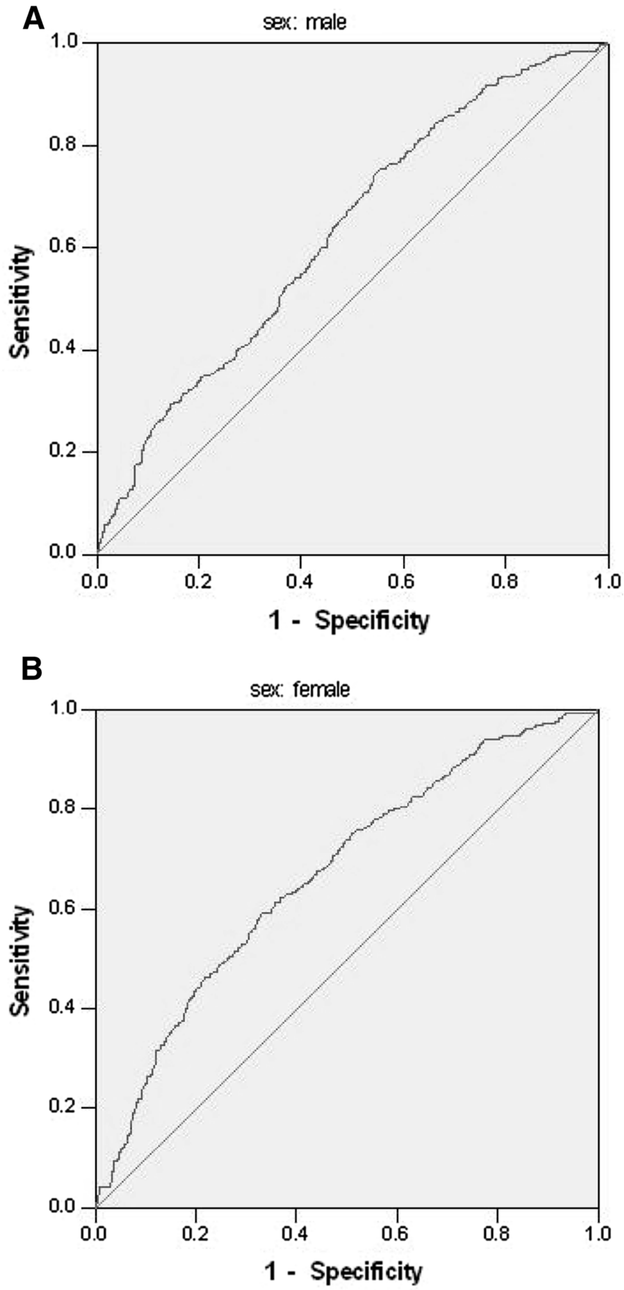

Fig. 1 The ROC curve demonstrating the most appropriate cut-off levels of BMI to detect hypertension in the studied population in different genders (**a** male, **b** female)

It should be added that the cross-sectional nature of the present study has precluded the causal inferences regarding the association between anthropometric measurements and hypertension. Participant selection, on the other hand, has reduced the generalizability of the findings. Large prospective studies are needed to better evaluate the impact of these anthropometric variables on blood pressure regulations.

6 Conclusion

This study quantified the relationship between blood pressure levels and BMI, WC, HC and WHR in a representative sample of Iranian population and reported that general obesity but not abdominal obesity is directly linked with higher blood pressure levels.

Moreover, this study demonstrated that BMI is the most accurate predictive tool in detecting hypertensive cases, adding that increased waist circumference (more than 75%) is also associated with an increase in systolic/diastolic BP values.

Controlling the excess weight through addressing the quality of foods as well as encouraging individuals to exercise and adopt healthy lifestyles, therefore, should be a priority in educational and preventive strategies, aiming to minimize the risk of hypertension and its subsequent complications.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no competing interest.

Ethical approval The Research Ethics Committee of the Endocrine and Metabolism Research Center (EMRC) approved the protocol of this study.

Informed consent Informed consent was obtained from individual participants included in the study.

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