# Neck circumference, visceral adiposity, and hypertension: does upper body adiposity outperforms visceral adiposity in terms of hypertension predictions?

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## Abstract

**Background:** This study set up to determine which of the neck circumference (NC), as a predictor of upper body sub-cutaneous fat, or visceral adipose tissue, as an indicator of intra-abdominal fat mass, can be the better predictor of hypertension.

**Material and methods:** 130 overweight/obese women took part in this cross-sectional study conducted in November 2017. Blood pressure, anthropometric measurements, and body composition were determined. Pearson's correlation coefficients, multivariate logistic regression, and the area under the curve of the receiver operator characteristic curves analyses were performed.

**Results:** Mean age, weight, and neck circumference were 39.93 ± 8.71 years, 74.26 ± 9.86 Kg, and 35.06 ± 1.74 cm, respectively. There was a significant correlation between neck circumference and visceral adipose tissue with systolic blood pressure ($r = 0.32$, $p = 0.001$) ($r = 0.57$, $p < 0.001$) and diastolic blood pressure ($r = 0.23$, $p = 0.008$) ($r = 0.45$, $p < 0.001$), in the respective order. According to the results of the ROC curve analysis, visceral adipose tissue and neck circumference predicted hypertension with an accuracy of 81 and 65 percent, respectively. In addition, the probability of having increased blood pressure increased with higher visceral adipose tissue ($OR = 1.22$, $p < 0.001$).

**Conclusions:** According to our findings, abdominal obesity and high NC in implication with overweight or obesity can more exactly evaluate hypertension risk.

**Key words:** obesity; hypertension; neck circumference; visceral adiposity; body fat distribution

*Arterial Hypertens. 2021, vol. 25, no. 1, pages: 22–28*
*DOI: 10.5603/AH.a2021.0005*

## Introduction

Hypertension is one of the risk factors to predict cardiovascular diseases (CVD) including ischemic or hypertensive heart disease, as well as chronic kidney diseases [1]. Globally, 1.4 billion people had hypertension in 2010 [2], and is anticipated to affect 30% of the worldwide population by the year 2025. Hence, hypertension remains as one of the serious issues of medical and public health and its burden is

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remarkably greater than before throughout the world both in developed and developing countries [2].

The causes of elevated blood pressure (BP) are multifarious and related to numerous environmental and genetic factors [3]. Some studies have reported that obesity and adiposity are the common risk factors for hypertension [4–6]. Several epidemiological studies also demonstrated significant associations between anthropometric measurements and hypertension [7, 8]. It has been shown that waist circumference (WC) significantly associated with abdominal adiposity and it is also highly correlated with CVD risk factors [9]. This anthropometric tool is generally an acceptable measure, but it has some drawbacks, for instance, the anatomic marker of waist size could not be observed easily and could vary greatly particularly in obese persons, which is influenced by nutrition, breathing, and diseases. Furthermore, the clients may not be comfortable being measured by exposing the midsection and their privacy should be respected [10].

Recently, neck circumference (NC) has received abundant attention from the researchers. It is suggested that NC would be a better measure than waist measurements since it is simple, inexpensive, not time-consuming, and not invasive. NC is also a more reliable and advantageous anthropometric parameter applied as an alternative to determine the upper body subcutaneous adipose tissue distribution [11, 12]. Numerous studies in large populations, demonstrated that NC is capable of predicting cardiovascular risk factors, fatty liver disease, type 2 diabetes, insulin resistance, and metabolic syndrome in adults [11–14].

Another measurement is visceral adipose tissue (VAT) which significantly involved in central obesity and is located in the abdomen and intra-abdominal contents [15]. VAT is known as an exceptional pathogenic fat depot and giving metabolic risk beyond normal anthropometric measures like body mass index (BMI) and WC [16]. Besides, recent studies have shown that VAT is linked to a greater atherosclerotic danger profile [17], adverse cardiovascular events [7], development of insulin resistance [16, 18], and incidence of diabetes among obese adults [19].

Studies show that NC and VAT are associated with CVD by contributing to the development of hypertension. Some former investigations have explored the relationship of NC [11, 14, and 20] and high VAT [21–23] with hypertension, and often the results were inconsistent. Also, none of these researches have compared NC with VAT, with respect to their link with BP. Early identification of pre-hypertension and hypertension will help in decreasing the incidence of hypertension in the adult population in the near future, thereby significantly reducing the hypertension-related health burden. Therefore, this study was set up; firstly, to evaluate the association of NC, as an indicator of upper body subcutaneous adipose tissue, and VAT, the key indicator of intra-abdominal fat mass, with hypertension; and secondly, to specify the most favorable cut-off points of NC and VAT to show one is better in terms of hypertension prediction.

## Material and methods

### Study participants

This cross-sectional study was conducted on 130 overweight/obese (BMI > 25) women aged 19–64 years that were living in Sardrood-Tabriz, Iran during November 2017. The research aims were described to participants individually before entering the study and informed written agreement was acquired from all participants. Ethical committee of Tabriz University of Medical Sciences, Tabriz, Iran, certified the study protocol (reference number: IR.TBZMED.REC.1396.291).

### Anthropometric measurements

Weight and height of the participants were measured by a balance beam scale (SECA) and a portable stadiometer, with the accuracy of ± 0.1 cm and ± 0.1 kg, in the respective order; they clothed scantily wearing no shoes. NC was measured in the standing position, head at the level of the thyroid cartilage. WC was measured in the middle of the inferior rib margin and the iliac crest. Hip circumference (HC) was measured at the maximum circumference around the buttocks. A flexible measuring tape with the accuracy of ± 0.5 cm was used to measure NC, WC, and HC. In addition, waist to hip ratio (WHR) and waist-to-height ratio (WHtR) were determined.

### Body composition assessments

Body composition parameters including fat mass (FM), skeletal muscle mass (SMM), and VAT were measured by the application of A hand to-hand impedance analyzer (OMRONBF511, made in Germany) [24]. They were told to empty their bladder prior to measurements. They were also requested to first wipe the sole of the feet using a damp tissue and then stand over the electrodes of the instrument. Details such as weight, height, age and gender were given as input into the machine and outputs were registered. This device was held while both arms were strained straight in front of the body.

### BPs measurements and definition

BP was measured by following standard guidelines. The individual was made comfortable and sit at least for 5 minutes on chair. A mercury sphygmomanometer was used for measuring systolic blood pressure (SBP) and diastolic blood pressure (DBP) on the right arm with and stethoscope and the average of the two measurements was taken. Participants were advised not to drink alcohol, tea or coffee, smoke and to take exercise for at least 30 minutes before measuring BP. The "2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults" were used to set elevated BP (SBP between 120- and 129-mm Hg and DBP lower than 80 mm Hg) and stages 1 and 2 of hypertension (SBP of 130 mm Hg or greater or DBP of 80 mm Hg or greater) [25].

### Statistical analysis

Since all the variables have normally distribution, descriptive statistics, mean and standard deviation (SD) were calculated for the quantitative variables (age, weight, BMI, NC, Fat mass, VAT, SBP and DBP). Pearson's correlation coefficients were used to study the relations between NC with SBP and DBP, as well as the link between NC, anthropometric measurements (BMI, WHtR, WHR and WC) and body composition (FM and VAT). The receiver operating characteristics (ROC) analysis was applied to define the performance and cutoffs of variables. The total biased power of a diagnostic test was shown by the ROC curves. A test appearance its curve nearer to the upside left corner. The area under the curve (AUC) is a scale of the predictive ability of test. An ideal test has an AUC of 1.0, and an AUC of 0.5 indicates the test achieves no preferable than accident. Variables sensitivity and specificity were determined for every feasible cutoff point to distinguish the most satisfactory cutoff value. The best sensitivity and specificity were the contents providing topmost amounts from the ROC curves [26]. Also, multivariate logistic regression analyses were calculated. These analyses were adapted for confusing variables such as weight and age. Odds ratios (OR) with 95% confidence intervals (CI) were determined. Statistical analyses were done by SPSS version 23. P values less than 0.05 were considered as statistically significant.

## Results

In our studied women, the mean of age, weight and NC were 39.93 ± 8.71, 74.26 ± 9.86 and 35.06 ± 1.74, respectively. Sixty-three-point one percent (n = 82) of the participants had elevated BP or hypertension. Table 1 presents other descriptive and anthropometric measures of the study population.

**Table 1.** Clinical characteristics of the study participants (n = 130)

| Variables | Mean (SD) |
|---|---|
| Age [years] | 39.93 (8.71) |
| Weight [kg] | 74.26 (9.86) |
| Height [cm] | 155.46(5.12) |
| BMI [kg/m$^2$] | 30.65 (3.94) |
| NC [cm] | 35.06 (1.74) |
| Fat mass (%) | 43.81 (4.94) |
| VAT | 8.47 (2.008) |
| SBP [mm Hg] | 114.00 (14.93) |
| DBP [mm Hg] | 75.38 (9.61) |

BMI — body mass index; NC — neck circumference; VAT — visceral adipose tissue; SBP — systolic blood pressure; DBP — diastolic blood pressure

Pearson's correlation coefficients between BP and independent variables are shown in Table 2. According to the results, age (r = 0.59, p < 0.001) (p = 0.53, p < 0.001), BMI (r = 0.37, p < 0.001) (r = 0.25, p = 0.004), WC (r = 0.34, p < 0.001) (r = 0.20, p = 0.01), NC (r = 0.32, p < 0.001) (r = 0.23, p = 0.008), FM (r = 0.26, p = 0.003) (r = 0.20, p = 0.01), and VAT (r = 0.57, p < 0.001) (r = 0.45, p < 0.001) were considerably associated with SBP and DBP, in the respective order.

Table 3 presents that using the ROC Curve Analysis, VAT ≥ 10 with 81% accuracy were calculated to be the best cutoff levels to detect patients with hypertension for overweight and obese women (95% CI: 0.74–0.88). In addition, NC cutoff values for hypertension were determined to be ≥ 38 cm with 65% accuracy (95% CI, 0.56–0.76). FM cutoff values for overweight and obesity were determined to be ≥ 44 % with 65% accuracy (95% CI: 0.56–0.75). The ROC Curve of NC, BMI, FM and VAT presented in Figure 1.

As shown in Table 4, the odds of having elevated BP increased significantly with higher VAT (OR = 1.22, p < 0.001), following the adjustment for weight and age. In the other word, the participants with higher VAT significantly had a greater risk of having elevated BP.

## Discussion

It is very important that we recognize the elevated BP, before progress to hypertension. To our best knowledge, this study is the first to investigate the

**Table 2.** Pearson's correlation coefficients between variables and blood pressure; Diastole blood pressure

| Variables | SBP | | DBP | |
|---|---|---|---|---|
| | r | p | r | p |
| Age [years] | 0.59 | **< 0.001**** | 0.53 | **< 0.001**** |
| Weight [kg] | 0.22 | **0.01*** | 0.13 | 0.11 |
| Height [cm] | –0.21 | **0.01*** | –0.19 | **0.02*** |
| BMI [kg/m$^2$] | 0.37 | **< 0.001**** | 0.25 | **0.004*** |
| WC [cm] | 0.34 | **< 0.001**** | 0.20 | **0.01*** |
| HC [cm] | 0.21 | **0.01*** | 0.09 | 0.30 |
| WHR | 0.27 | **0.002*** | 0.20 | **0.01*** |
| WHtR | 0.40 | **< 0.001**** | 0.26 | **0.002*** |
| NC [cm] | 0.32 | **< 0.001**** | 0.23 | **0.008*** |
| FM (%) | 0.26 | **0.003*** | 0.20 | **0.01*** |
| SMM (%) | –0.21 | **0.01*** | -0.17 | **0.04*** |
| VAT | 0.57 | **< 0.001**** | 0.45 | **< 0.001**** |

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed); BMI — body mass index; NC — neck circumference; WC — waist circumference; HC — hip circumference; WHR — waist to hip ratio; WHtR — waist-to-height ratio; FM — fat mass; SMM — skeletal muscle mass; VAT — visceral adipose tissue; SBP — systolic blood pressure; DBP — diastolic blood pressure

**Table 3.** Area under the curve (AUC), sensitivity, specificity and cutoff points for determining the hypertension, in overweight and obese women, with using ROC analysis

| Variables | AUC | (95% CI) | | Cutoff | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|---|
| | | Lower | Upper | | | |
| Age [years] | 0.82 | 0.75 | 0.89 | ≥ 47 | 52.08 | 90.24 |
| Weight [kg] | 0.65 | 0.56 | 0.76 | ≥ 74.4 | 66.67 | 68.39 |
| BMI [kg/m$^2$] | 0.71 | 0.62 | 0.81 | ≥ 34.6 | 39.58 | 90.24 |
| WC [cm] | 0.68 | 0.59 | 0.78 | ≥ 105 | 60.42 | 75.61 |
| HC [cm] | 0.63 | 0.53 | 0.73 | ≥ 116 | 29.17 | 91.46 |
| WHR | 0.63 | 0.53 | 0.73 | ≥ 0.99 | 27.08 | 84.15 |
| WHtR | 0.68 | 0.59 | 0.78 | ≥ 0.71 | 35.42 | 89.02 |
| NC [cm] | 0.65 | 0.56 | 0.76 | ≥ 38 | 18.75 | 97.56 |
| FM (%) | 0.65 | 0.56 | 0.75 | ≥ 44 | 66.67 | 65.65 |
| VAT | 0.81 | 0.74 | 0.88 | ≥ 10 | 54.17 | 89.02 |
| RMR (%) | 0.63 | 0.53 | 0.73 | ≥ 1589 | 14.58 | 96.34 |

BMI — body mass index; NC — neck circumference; WC — waist circumference; HC — hip circumference; WHR — waist-to-hip ratio; WHtR — waist-to-height ratio; FM — fat mass; VAT — visceral adipose tissue; AUC — area under the curve

links between NC and VAT with hypertension, in Iranian overweight/obese women. Our findings revealed that there was a relationship between NC with SBP and DBP. This result was in accord with previously published data in Asian and European populations on different age groups and sample sizes [27, 28]. In the study on Chinese population, Zhou et al. found that NC had significant association with BP and hypertension [11]. In another study, Assyov et al. reported that there was a positive association between NC and hypertension in univariate analysis. Though, when adjusted for age and WC, the association lost its statistical significance in females [29]. The results of a cross-sectional study in the US also demonstrated that in each category of BMI, participants with high NC had a Greater risk for high BP [30]. The specific mechanisms justifying the relations of NC with hypertension are not completely confirmed. It has recommended that upper-body subcutaneous fat potency influences the arterial BP and the progress of hypertension by discharging considerable amounts of systemic free fatty acid, which could to bring vascular damage, aggravate endothelial cell dysfunction and insulin resistance, and increase oxidative stress and very-low-density lipoprotein cholesterol production [31–34].

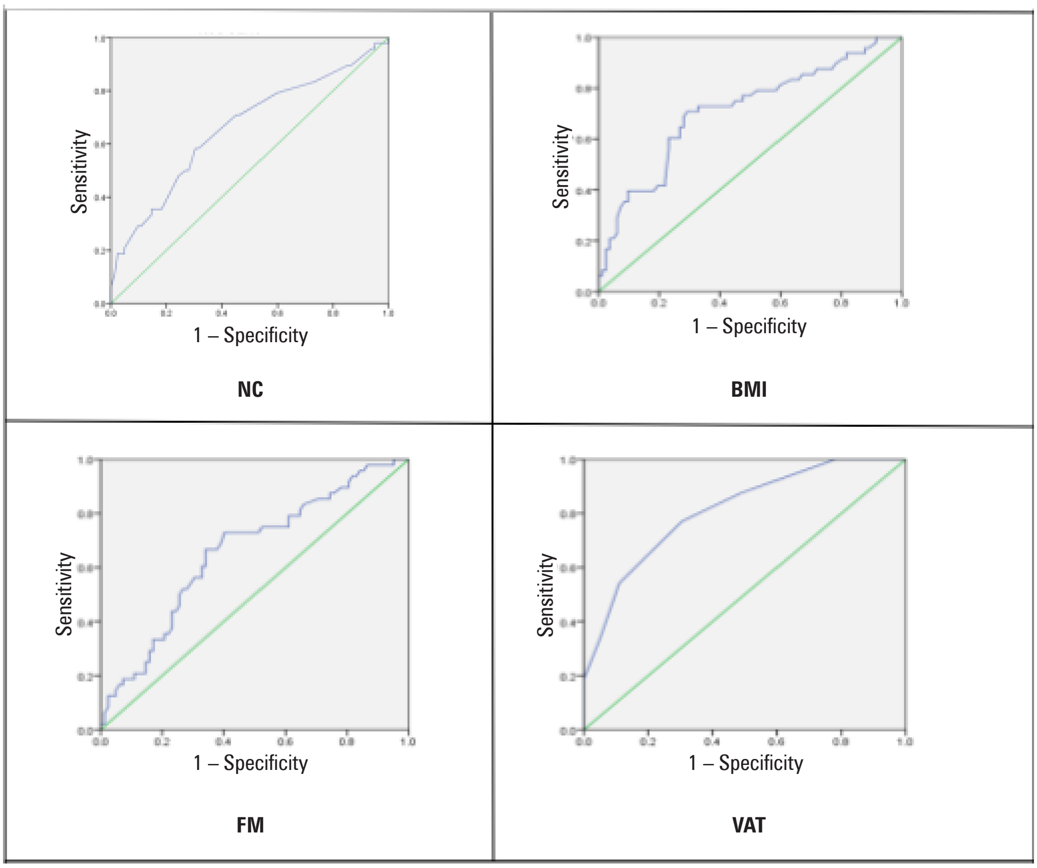


**Figure 1.** The ROC curve of neck circumference (NC), body mass index (BMI), fat mass and visceral adipose tissue (VAT)

**Table 4.** Multivariate logistic regression analysis of associations between the selected risk factors and hypertension

| Variables | $\beta$ | OR | CI | p value |
|---|---|---|---|---|
| Height [cm] | –0.23 | 0.78 | 0.24–2.56 | 0.69 |
| BMI [kg/m$^2$] | 0.12 | 1.13 | 0.30–4.26 | 0.85 |
| WC [cm] | 0.37 | 1.46 | 0.11–17.92 | 0.76 |
| HC [cm] | 0.28 | 1.33 | 0.44–4.01 | 0.60 |
| WHR | 17.83 | 1.1 | 0–2.44 | 0.78 |
| WHtR | –64.11 | 0.00 | 0–8.78 | 0.70 |
| NC [cm] | –0.245 | 0.78 | 0.54–1.11 | 0.17 |
| FM (%) | 0.20 | 1.23 | 0.92–1.64 | 0.15 |
| SMM (%) | 0.45 | 1.57 | 0.84–2.93 | 0.15 |
| VAT | 1.47 | 1.22 | 0.11–1.44 | **< 0.001*** |
| SMM (%) | 0.45 | 1.57 | 0.84–2.93 | 0.15 |
| RMR | –0.01 | 0.98 | 0.94–1.03 | 0.56 |

Adjusted for age and weight; *Correlation is significant at the 0.05 level (2-tailed); BMI — body mass index; NC — neck circumference; WC — waist circumference; HC — hip circumference; WHR — waist-to-hip ratio; WHtR — waist-to-height ratio; FM — fat mass; SMM — skeletal muscle mass; VAT — visceral adipose tissue; SBP — systolic blood pressure; DBP — diastolic blood pressure

Findings about the association of independent variables and hypertension using ROC Curve Analyses demonstrated that VAT is a strong predictor of hypertension and it has finest cut-off points with best-balanced specificity and sensitivity for the hypertension. We evaluated the prognostic power of anthropometric measurements for hypertension and found that the AUC for VAT was more than AUC for total body fat mass and other anthropometric indices. Similar to current study, Cassano reported an epidemiological association between adiposity and hypertension [35]. Also, the results of George researches support our research hypotheses: there was a link between measures of central adiposity with larger risks (50–65%) of hypertension than total adiposity (44–45%) [36].

Results of our study about odds ratios for factors associated with hypertension highlights that increased VAT was robustly associated with elevated BP. Similar to our study, in a cohort of Japanese Americans, the intra-abdominal fat area was reported as a major risk factor for hypertension, even after adjustment for WC, abdominal subcutaneous fat area and total subcutaneous fat area [21]. In addition, Dallas Heart Study revealed that both baseline and gain of visceral fat were linked to a greater relative risk for hypertension. In this manner, gain of visceral and abdominal subcutaneous fat was also considerably linked to higher SBP, even after 7 years follow up [15, 22]. Likewise, in a middle-aged Chinese population, there was a significant link between excess VAT and higher risk of hypertension and prehypertension [23]. Some studies proposed that local influences from fat surrounding the kidneys might influence the progress of hypertension [15].

Although this study is limited by the cross-sectional nature and small sample size, it does provide direction and insight for future researchers to build upon. Additional large-scale, prospective studies could assistance to improve explain and confirm associations between anthropometric measurements and hypertension.

## Conclusion

The current study reported the value of the interactions of various anthropometric indices of obesity for assessing the risk of hypertension. As BMI is a weight-for-height measure, it is not capable of showing the difference between FM and FFM. Moreover, WC measurements are not capable of differentiating VAT and subcutaneous adipose tissue. In fact, abdominal obesity and high NC in implication with overweight or obesity can more exactly evaluate hypertension risk. Our findings also propose that advanced imaging tools can prepare a more detailed phenotypic characterization of obesity than usual anthropometric indices, consenting greater distinction of hypertension and cardiovascular complications. Also, we propose that treatments pointed at redistribution of fat mass; away from the VAT toward the lower body subcutaneous depot. This manner may be more helpful than only aiming decrease body mass, for stopping CVD in obesity.

## Conflict of interests

There are no conflicts of interest in terms of the publication of this paper.


## Funding

This research was carried out without any particular funding from any public, commercial, or non-profit agencies.

## Acknowledgements

The authors would like thank all the women who participated in this study.


## Authorship

M.E.V. and M.A. designed research; M.E.V. conducted research; L.F.G. analyzed data; and M.E.V., R.M.G. and M.A. wrote the paper. The final manuscript was read and approved by all authors.

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