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Can anthropometric indices predict the chance of hypertension? A multicentre cross-sectional study in Iran

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ABSTRACT

Objectives This study aims to assess the prevalence of hypertension (HTN), and determine the relationship between HTN and anthropometric indices including fat distribution, body mass index (BMI), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) in Shiraz Heart Study.

Setting In this cross-sectional study, subjects were enrolled in 25 clinics in Shiraz. I.R. Iran between 2019 and 2021.

Participants A total number of 7225 individuals were selected, aged between 40 and 70 years of whom 52.3% were female. Among the people living in Shiraz, individuals living far from clinics, cases of mental or physical disabilitiy and documented cardiovascular diseases were excluded.

Primary and secondary outcome measures Primary outcome: The association of body composition, WHR, WHtR and BMI with HTN.
Secondary outcome: The sensitivity and specificity of the WHtR for the prediction of HTN.

Results HTN prevalence was 19.3%. Obesity prevalence was estimated to be 28.5%. WHR and lean body mass showed a significant association with HTN ($p<0.05$). Receiver operating characteristic for WHtR yielded an area under the curve of 0.62 (95% CI 0.61 to 0.64) and 0.63 (95% CI 0.62 to 0.65) for males and females, respectively. The optimal threshold value yielded 0.54 in men and 0.61 in women. The sensitivity was 72.3% and 73.9% in women and men, with specificity of 48.4% and 44.3%, respectively.

Conclusion HTN had a meaningful association with all the noted anthropometric indices. WHtR performed well as a predictor of HTN.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study includes a relatively large number of participants with several times of data collection as follow-up.
⇒ Considering standard methods for measurements and data collection, as well as clustering of population.
⇒ Our study merely involved Shiraz citizens, which in turn curbs the generalisation of our results to other urban and rural residents.
⇒ Due to the cross-sectional design of this study, we could not assess the causal and temporal relationship between variables.
⇒ The distribution of age was not uniform and not all ages were covered.

INTRODUCTION

Hypertension (HTN) or high blood pressure is characterised by persistently elevated pressure in the blood vessels, according to WHO definition.[1] It is the most common non-communicable disease that is considered as preventable risk factor for cardiovascular diseases and overall mortality.[2–4] Approximately 1.28 billion people worldwide aged between 30 and 79 years suffer from HTN.[1 5] Furthermore, its prevalence is growing annually due to factors such as ageing, unhealthy diets and sedentary lifestyles.[6] Moreover, an increase of about 100% was observed between 1990 and 2019 globally.[7]

HTN has an increasing prevalence in low-income and middle-income countries, while high-income countries have witnessed a modest decrease in the past two decades.[6]

Studies have shown that the prevalence of HTN has been increasing in Iran as a low-income/middle-income country in the Middle East.[8 9] It was estimated at 31% in men and 27% in women among adults above 25 years old in a study in Yazd, Iran.[8] In a cross-sectional study on 10 111 individuals above 30 years old in Fasa Persian cohort (2019), HTN had about 46.6% prevalence rate. The first and the second stages of HTN were detected in 16.1% and 17.9% of the population, respectively.[10] In a meta-analysis by

Afsargharehbagh *et al*,[11] including 48 studies on 417 392 individuals, pre-HTN and HTN had an overall prevalence rate of 31.6% and 20.4%, respectively.[11]

In addition, the financial burden of HTN is extensive. It can arise from direct healthcare costs including medications, workups, visits and hospitalisations, or indirect costs due to ensuing cardiovascular, kidney diseases and morbidity-related non-functionality.[12] It has cost the USA about US$51.2 billion during 2012 and 2013.[13] Likewise, the global financial burden of HTN is estimated to comprise 10% of the world's total healthcare expenditure (US$370 billion).[12]

A significant correlation has been observed between HTN and many factors such as age, obesity, body mass index (BMI), physical activity, diabetes, hyperlipidaemia, rural inhabitation, serum levels of high-density lipoprotein, triglyceride, blood urea nitrogen and alkaline phosphatase.[8 10] furthermore, there has even been some evidence that hypertensive people have lower levels of happiness in life.[14] Diabetes mellitus, as a risk factor for HTN, causes significantly worse major adverse cardiac events following percutaneous coronary intervention.[15 16]

Regarding the risk prediction of HTN, anthropometric indices such as waist circumference (WC), hip circumference (HC), BMI, waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) have been adopted frequently; among them, BMI and WC are the most regular.[17] BMI, taking into account only height and weight, is not indicative of fat distribution. On the other hand, WC alone is not sensitive to variations in lean body mass, build or height.[17] In other words, central obesity, compared with total obesity plays a more important role in predicting cardiometabolic risks, as WHtR at some studies has shown to be a better predictive factor for cardiometabolic diseases.[18]

Shiraz Heart Study (SHS) is the first cardiovascular-oriented cohort, which is conducted in Iran.[9] Previous views on this cohort have revealed a 45.5% prevalence (95% CI 44.4% to 46.7%) of metabolic syndrome in Shiraz adult population.[19] This study aimed to determine the correlation between HTN with central and total obesity indicators, including BMI, WHR and WHtR. The novel aspect of our paper is that we merge these findings with soft lean mass data to assess the role of SLM in this regard.

METHODS

This cross-sectional study is a part of SHS, which is being performed in Shiraz, Iran.[9] It started in 2019 and the follow-up interval was 2 years. In-depth quality assurance and quality control were carried out in this study.[20 21] Patients who resident in Shiraz urban areas in the past year with no migration plan in the upcoming few years were enrolled. Living far from study centres, mental or physical disability, and documented cardiovascular diseases were the exclusion criteria. Family physician clinics, as the study clusters, carried out the data collection.

To measure blood pressure, we acted according to the guideline issued by the American Society of Hypertension for office blood pressure measurement. Each participant was asked to rest for more than 30 min on a chair. Patients were asked not to have any caffeine, exercise or smoking for at least 30 min prior to measurement. Participants were insured to have empty bladders. No conversation occurred during BP measurement. Then, the blood pressure was measured consecutively in both arms via a digital sphygmomanometer and the higher pressure was used. Measurement was performed two more times, each 2 min apart (totally three times). Next, these three values were averaged and the outcome was recorded as the participant's blood pressure.[22] It should be noted that individuals who were on medical therapy for HTN were considered as hypertensive, irrespective of their pertinent blood pressure. Anthropometric indices were measured according to similar training instructions to family physician assistants. Fat distribution was measured via a Jawon medical body composition analyzer (x-contact 350).

The authors define the first stage of HTN as a systolic blood pressure (BP) of 140 mm Hg or higher or diastolic blood pressure of 90 mm Hg or above.[23] Stage II of HTN was defined as having a systolic BP equal to or above 160 mm Hg or a diastolic pressure of 100 mm g or above. Anthropometric status was represented via BMI classes. A BMI of less than 18.5 kg/m^2 was classified as underweight, between 18.5 kg/m^2 and 24.9 kg/m^2 as normal, between 25 kg/m^2 and 29.9 kg/m^2 as preobesity or overweight, between 30 kg/m^2 and 34.9 kg/m^2 as grade I obesity, between 35 kg/m^2 and 39.9 kg/m^2 as grade II obesity, and over 40 kg/m^2 as grade III or morbid obesity.[24] WHR was measured as the ratio of WC (cm) to HC (cm). Here, we classified WHR into two groups of normal and obese, in agreement with a report from a WHO expert consultation.[25] WHRs of higher than 0.85 and 0.90 in women and men, respectively, were considered obese. Amounts equal to or less than these values were classified as normal. Height was measured as the nearest half centimetre in standing position, without shoes and weight was measured as the nearest 0.1 kg without heavy clothes. The WC was measured as the middle point between the upper border of the iliac crest and the lower border of the lower rib with a tape measure with an accuracy of half centimetre, and HC was considered as the widest portion of the buttocks in centimetres.[26]

Considering different statures and body compositions, the participants were primarily grouped by their sex type, and HTN prevalence was assessed in each group. Moreover, the participants were clustered into six groups based on BMI. The frequency of each BMI cluster was determined. Next, individuals were classed as normal or abnormal depending on WHR.

Statistical analysis

Normality of data was checked by means of amount of kurtosis and skewness as well as Shapiro-wilk test . Descriptive statistics applied included mean and SD for

Table 1 Demographic and baseline data of 7225 adults in Shiraz Heart Study 2021

Variable	Mean/n	SD/per cent
Age, years—mean (SD)	52.14	8.01
Sex—frequency (%)		
Male	3445	47.7
Female	3780	52.3
SLM—mean (SD)		
Left arm	3.57	0.67
Right arm	3.57	0.68
Left leg	8.97	1.72
Right leg	9.0	1.73
Trunk	24.42	4.44
BMI—mean (SD)	27.92	4.54
WHtR—mean (SD)	0.59	0.07
HTN	1396	19.3

Data were presented as mean (SD) and number (per cent) for continuous and categorical variables.
BMI, body mass index; HTN, hypertension; SLM, soft lean mass; WHR, waist-hip ratio; WHtR, waist-height ratio.

quantitative variables and frequency for qualitative variables. Analytical statistics used included χ^2 test and independent t-test. The binary logistic regression was used to investigate the association between HTN and BMI level. The receiver operating characteristic (ROC) curve was also plotted to assess the sensitivity and specificity of WHtR in predicting HTN. All analyses were done using SPSS statistics V.26.0. The significance level was considered at 5%.

Patient and public involvement

No patient involved.

RESULTS

A total number of 7225 adults with the mean age of 52.14±8.01 years (range: 40–70) were enrolled. Female participants comprised 52.3% of the study population. Demographic and beeline data were summarised in table 1

HTN prevalence was 19.3% (1396 individuals), among whom 13.2% had systolic HTN, 13.4% diastolic HTN and 7.3% had both. The male population, compared with females, had a higher prevalence of HTN (table 2), making them 1.57 times more prone to HTN (OR 1.57, 95% CI 1.40 to 1.78, p<0.001).

BMI marked 73.6% of the study population as overweight or obese. To describe more precisely, overweight individuals amounted to 45.1%, while 28.5% had different degrees of obesity (figure 1). BMI was significantly associated with HTN in both genders. OR extracted from binary logistic regression showed a significant increase in HTN prevalence with groups of higher BMI (p<0.001) in both men and women (table 3 and figure 2).

The WHtR was meaningfully higher in people with HTN compared with the ones without it. This metric was correlated with HTN in both male and female participants. Accordingly, the ROC was plotted, for the two genders (figure 3 and table 2). The area under curve

Table 2 Distribution of HTN in male and female gender grouped by WHR and SLM, in 7225 adults in Shiraz Heart Study 2021

	Female			Male		
Variable	HTN	No HTN	P value	HTN	No HTN	P value
Frequency (%)	603 (16)	3177 (84)	–	793 (23)	2652 (77)	–
WHR						
Normal—frequency (%)	64 (10.3)	558	<0.05	83 (11.7)	627	<0.05
Abnormal—frequency (%)	547 (16.2)	2839		752 (25.6)	2187	
Mean (SD)	0.94 (0.07)	0.92 (0.07)	< 0.001	0.96 (0.05)	0.94 (0.05)	< 0.001
SLM						
Left arm—mean (SD)	3.17 (0.44)	3.12 (0.42)	0.027	4.18 (0.60)	3.99 (0.55)	< 0.001
Right arm— mean (SD)	3.16 (0.44)	3.11 (0.42)	0.046	4.19 (0.61)	4.00 (0.56)	< 0.001
Left leg—mean (SD)	8.10 (1.20)	7.94 (1.12)	0.006	10.48 (1.73)	9.92 (1.50)	< 0.001
Right leg—mean (SD)	8.10 (1.18)	7.95 (1.13)	0.011 s	10.52 (1.72)	9.97 (1.51)	< 0.001
Trunk—mean (SD)	21.69 (2.74)	21.48 (2.69)	0.118	28.40 (4.02)	27.25 (3.66)	< 0.001
BMI—mean (SD)	30.64 (4.9)	28.71 (4.5)	< 0.001	28.04 (4.12)	26.30 (3.99)	< 0.001
WHtR—mean (SD)	0.65 (0.07)	0.61 (0.07)	0.001	0.58 (0.06)	0.55 (0.05)	0.001

BMI, body mass index; HTN, hypertension; SLM, soft lean mass; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

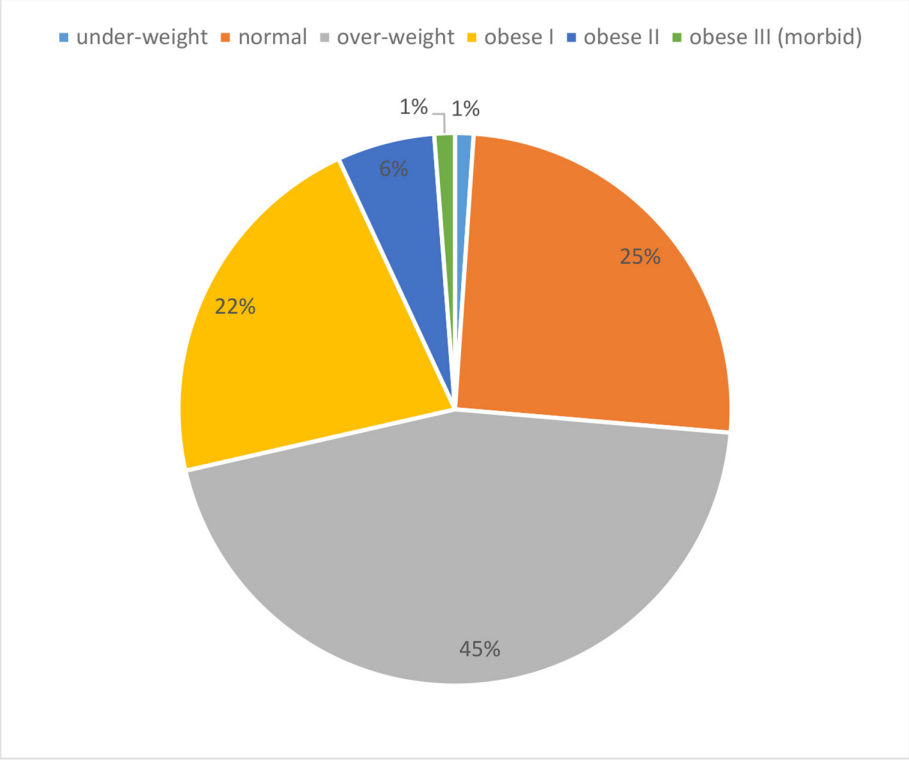

Figure 1 Anthropometric status distribution (BMI) in 7225 adults in Shiraz Heart Study 2021. BMI, body mass index.

(AUC) was achieved 0.62 (95% CI 0.61 to 0.64) and the sensitivity and the specificity of 73.9% and 44.31% for men, respectively, in the optimal threshold. These values were 0.63 (95% CI 0.62 to 0.65) for females with sensitivity and specificity of 72.31% and 48.38%. The optimal ratio threshold yielded 0.54 in men and 0.61 in women. Individuals with WHtR higher than their respective criteria should be suspected of HTN; however, corresponding sensitivity must be examined. With regard to the area under the ROC curve, WHtR had almost the same predictive capability in both genders with different thresholds. Except for trunk fat in female participants, other fat distribution indices were significantly correlated with HTN in both men and women. Nonetheless, the difference was more evident in the male gender (table 2).

DISCUSSION

As the results suggest, HTN prevalence among the study population was about 19.3%. BMI, WHR and WHtR all were significantly correlated to HTN prevalence. WHtR yielded an AUC of 0.62 in men and 0.63 in women which approved its predictive capability. Soft lean mass distribution had the same case, except for the trunk SLM in women.

Table 3 The logistic regression model (HTN (yes, nO) was dependent variable)

	Female			Male		
BMI	**OR**	**95% CI**	**P value**	**OR**	**95% CI**	**P value**
Under weight and normal	Reff					
Over weight	1.62	1.34 to 1.97	<0.001	1.45	1.08 to 1.93	0.011
Obese I	2.52	1.98 to 3.19	<0.001	2.34	1.74 to 3.14	<0.001
Obese II and obese III	3.92	2.61 to 5.88	<0.001	3.40	2.43 to 4.77	<0.001

WHR was abnormal in 84.12% and 80.27% of female and male participants, respectively, forming 82.29% of the study population. As the distribution of HTN was associated to WHR classes represent, there was a strong relationship between the WHR group and HTN in both male and female genders (p<0.05). In addition, the results of t-test showed that the difference of WHR among HTN and healthy group was significant in both men and women (p<0.001). WHR averaged to 0.94±0.05 and 0.92±0.07 in healthy men and women, and 0.96±0.05 and 0.94±0.07 in hypertensive individuals, respectively (table 2).
We pooled the underweight and normal BMI as well as obese II and obese III due to low sample size.
BMI, body mass index; HTN, hypertension; WHR, waist-to-hip ratio.

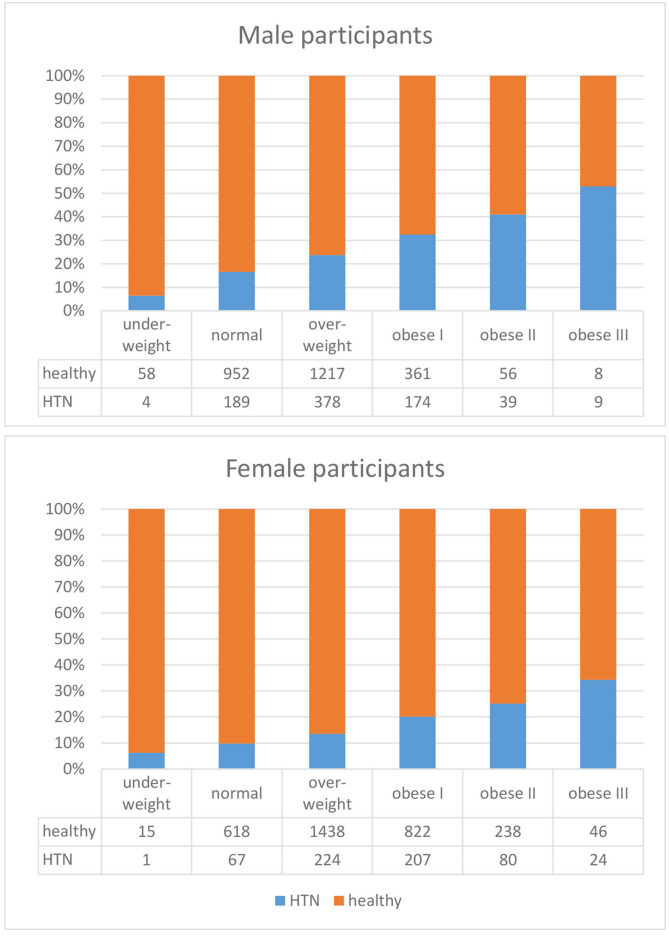

Figure 2 HTN prevalence over anthropometric status classes in men and women in 7225 adults in Shiraz Heart Study 2021. HTN, hypertension.

Reports are indicative of a higher prevalence of HTN in North America. Chobufo *et al*[27] stated a prevalence of 31.8% in people above 20 years from 2007 to 2016 in the USA. This value estimated to be 41% in 2017[28] and 41.2% in 2019 (35.5% after standardisation for age and sex).[29] Unhealthy diet and physical inactivity may be the major contributors for the relatively high prevalence of HTN in the USA compared with our study. Applying lower cut-offs of blood pressure for HTN, its prevalence will be reported higher. Classifying office patients with systolic blood pressures of equal to or more than 130 mm Hg or diastolic blood pressure of equal to or more than 80 mm Hg as hypertensive, HTN prevalence was 49.64% in the USA in 2017–2018.[30]

Surprisingly, HTN is more frequent in Europe, reaching 55% in 2017,[28] and 43.6% in 2019 (36.2% after standardisation for age and sex).[29] Although demographic features have key roles in this regard, variation of the sensitivity of the detection of HTN should not be overlooked.[31]

The resulting HTN prevalence is close to the conclusion reached by Afsargharehbagh *et al*[11] in a meta-analysis in 2019. As they estimated, covering 48 studies and about 417 392 individuals, HTN had a prevalence of 20.4%. Studies were done in Tehran (n=9) and five of them were conducted at the national level. The age range, however, was 15 –69 years. Taking into account the reported statistically significant linear trend with regard to age means, and the age range of our study being 40–70, it can be concluded that our study population had a generally lower blood pressure compared with the same age at other studies. This should not be attributed to the urban residency of our study population, as no significant difference was observed between urban and rural residents as

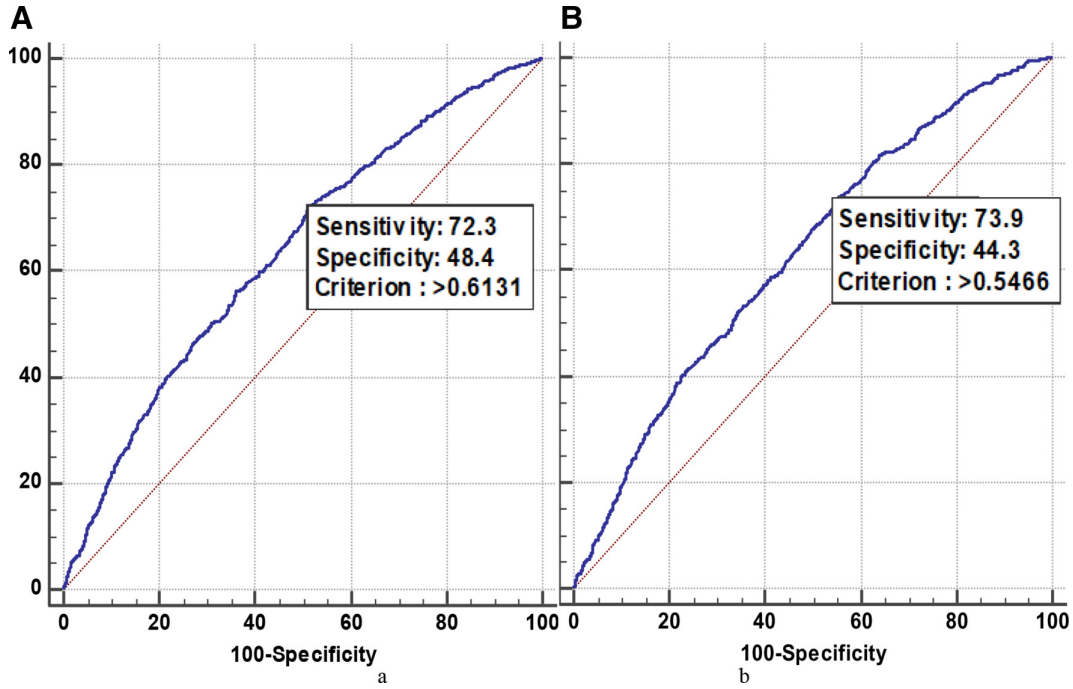

Figure 3 ROC curve for WHtR in women (A) and men (B) in 7225 adults in Shiraz Heart Study 2021. ROC, receiver operating characteristic curve; WHtR, waist-to-hip ratio.

to the HTN prevalence.[11] Kherameh cohort study labelled 27.7% of its study population as hypertensive.[32] Relatively higher BP was reported in the Fasa cohort study in 2020.[10] The authors have reported a prevalence of 16.1% for stage 1 HTN and 17.9% for stage 2. In more detail, systolic HTN had a prevalence of 7.6% and 7.6% in men and 8.5% and 10.3% in women for stages I and II, respectively. Diastolic HTN, on the other hand, had a prevalence of 27.2% and 13.4% in men and 28.7% and 14.1% in women at stages I and II. Put together, systolic HTN had a prevalence of 17.19% and diastolic HTN about 41.81%, which are far greater than the results in our study. Systolic and diastolic HTN in our study were estimated to have a prevalence of 13.2% and 13.4%, respectively. This could be explained by different cut-offs used, as we labelled systolic and diastolic BP above 140 mm Hg and 90 mm g as stage I, whereas Bijani *et al*[10] set a threshold of 130 mm Hg and 80 mm Hg. Mills *et al* estimated a global prevalence of 31.1%.[23] Low-income and middle-income countries generally had a higher prevalence of HTN (31.5%) compared with high-income countries (28.5%).[23] HTN in this study was also defined as systolic BP of 140 mm Hg or diastolic BP of 90 mm Hg or above.

Various studies have assessed obesity, defined as BMI equal to or above 30 kg/m^2. Vaisi-Raygani *et al*[33] studied its prevalence through a meta-analysis of 18 studies in 2019. It encompassed 29 943 individuals over 50 years old in Iran. They estimated a prevalence of 21.4% with a 95% CI of 16.9% to 26.6%. Here, we estimated this value to be 28.5% which is higher compared with the former. Rahmani *et al*[34] performing a meta-analysis on this matter in 2015, covered 144 studies and 377 858 persons older than 18 years between 1995 and 2010. Obesity prevalence was estimated to be 21.7% (95% CI 18.5% to 25%). Another large-scale cross-sectional study on 31 050 Iranian adult population in 2016 yielded a prevalence of 22.7% (95% CI 22.2% to 23.2%).[35] The lower prevalence of obesity in these studies could be due to different age groups, as we have enrolled adults above 40 years of age, while the mentioned studies set the lower range on 18 years. Djalalinia *et al*[35] estimated the obesity prevalence in age groups 45–54 years as 31.2% (95% CI 29.9% to 32.4%)), 55–64 years as 31.5% (95% CI 30.1% to 33.0%)) and 65–69 years as 29.5% (95% CI 27.0% to 32.0%)). These values, attributed to the same age groups as in our study, are more similar to our results.

The difference between men and women was significant in this matter in our study (men 18.78% and women 37.48%), which is consistent with the result obtained by.[33 35 36] It is probably due to the effect of oestrogen hormone in female gender on the metabolism and distribution of body fat which causes women to store more fat.[37]

In addition, our result on the significance of the association between BMI and HTN confirms the previously published studies.[38–41]

HTN has been associated with anthropometric states of being overweight or obese, which is in part developed through the accumulation of adipose tissue.[42] WHR, as reached in this study, has a strong correlation with regard to blood pressure, which is consistent with the previous studies.[38 41] Results drawn from the body composition analyzer suggest that soft lean mass in the left and right arms and legs, in addition to the trunk, are significantly higher in individuals with HTN compared with the healthy group. This finding is consistent with other studies.[43 44] The p value for all the five measurements in men was less than 0.001, whereas women had higher values. Exceptionally, the trunk soft lean mass in women did not manifest this feature (p=0.118). This could be due to normal variations in breast size and composing fat tissues in women.

The WHtR was higher in both men and women with HTN compared with the healthy group which supports previous studies.[18 41] Area under the curve was obtained as 0.62 for men and 0.63 for women, which is comparable to the results of other studies such as the meta-analysis by Deng *et al*.[41] They achieved an AUC of 0.649 for men and 0.679 for women. Khader *et al*[38] reached an AUC of 0.72 for women and 0.66 for men in recently diagnosed HTN and 0.82 and 0.73 for women and men previously diagnosed with HTN, respectively. The WHtR is a good indicator for the prediction of hypertensive patients and in some circumstances, it performs even superior to BMI and WHR.[41] It has also been observed that setting a threshold for WHtR (0.5) detects more people at early health risk compared with using both BMI and WC.[17 18] According to our results regarding the ROC curve for WHtR, we suggest a cut-off of 0.54 in men and 0.61 in women.

CONCLUSIONS

In this study, we estimated the prevalence of HTN in the Shiraz Heart Study to be 19.3%. HTN has a meaningful association with all the noted anthropometric indices, that is, BMI, WHR and WHtR. In addition, the association between HTN and body composition is such that there is a statistically clear correlation between high blood pressure and the accumulation of subcutaneous fat in different parts of the body, except for women's trunk fat. WHR and WHtR perform superior to BMI in predicting cardiovascular disease risks. We also recommend WHtR as the best predictor for HTN.

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Contributors HBD and MJZ conceived the idea of the manuscript and, in cooperation with AA-K, NP, MS, IR-J, SSM and FZ collected, analysed and interpreted the data. AA-K, ES, AN and SM drafted the manuscript. HBD, MS, AS, MK, SS, MH and MB revised the manuscript and acted as the guarantor of the manuscript. All authors read and approved the final manuscript and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval Terms of the principles of the Helsinki Declaration were applied in this study and the Research Ethics Committee of Shiraz University of Medical Sciences approved it (No: IR.SUMS.MED.REC.1401.046). All subjects signed a written informed consent as the preliminary step.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement The datasets generated and/or analysed during the current study are not publicly available due to the statement of the ethics committee of SUMS but are available from the corresponding author on reasonable request.

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