Environmental Science and Pollution Research (2021) 28:46514–46522
https://doi.org/10.1007/s11356-020-10122-6

SELECTED CASE STUDIES ON THE ENVIRONMENT OF THE MEDITERRANEAN AND SURROUNDING REGIONS

Associations between body mass index, waist circumference, waist circumference to-height ratio, and hypertension in an Algerian adult population

Salima Taleb[1,3,4] · Kafila Boulaba[2] · Ahlem Yousfi[2] · Nada Taleb[2] · Basma Difallah[2] · Samira Negrichi[2,4]

Received: 5 March 2020 / Accepted: 13 July 2020 / Published online: 17 July 2020

Abstract

The aim of our study was to analyze the associations between anthropometric measures and high blood pressure (HBP) in Algerian patients. A cross-sectional study was conducted among 785 adults with normal BMI (248), overweight (253), and obese (284), who were assessed with measurement of systolic and diastolic blood pressure, weight, height, and waist circumference (WC). Body mass index (BMI) and waist circumference-to-height ratio (WHtR) were calculated. We released receiver operating characteristic (ROC) curves for each anthropometric parameter to assess its discriminant power predictive of HBP in patients. Obese had a higher mean weight, WC, WHtR, systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting glucose (FG), total cholesterol (TC), and triglycerides (TG) than overweight and normal weight. The prevalence of hypertension and diabetes was higher in obese than overweight and normal weight. Results showed that obesity increased the risk of hypertension by a factor of 1.54 (95% CI [1.15, 2.06], ($p = 0.004$). Pearson's correlation data analysis showed that there was no relationship between systolic blood pressure and anthropometric parameters (BMI, WC, and WHtR). Only DBP was negatively associated with WHtR in the overweight group. All these parameters had areas under the curve between 0.409 and 0.618.The cutoff value of anthropometric WHtR parameters associated with the risk of hypertension was higher among women than men regardless of the BMI group considered. Contrary to the data of the literature, the discriminating power of anthropometry in the prediction of the HBP is limited or absent whatever the value of the BMI.

Keywords BMI · Hypertension · Anthropometric parameters · Waist circumference-to-height ratio

Introduction

Hypertension—or elevated blood pressure—is a serious medical condition that significantly increases the risks of heart, brain, kidney, and other diseases (WHO (World Health Organisation 2019). Several meta-analyses have shown a log-linear relationship between high blood pressure and an increased risk of cardiovascular disease which increases considerably with age (Tackling and Borhade 2019. According to the World Health Organization, 39% of adults aged 18 years and over were overweight in 2016, and 13% were obese (WHO 2018). Currently, it is established that obesity increases the risk of diabetes, hypertension, and dyslipidemia, which have an impact on cardiovascular diseases (CVD) mortality and morbidity (Visscher and Seidell 2001; Klein et al. 2007).

Responsible editor: Lotfi Aleya

✉ Salima Taleb
talebsalima@yahoo.fr

1 FESSNL. Applied Biology Department, University Larbi Tbessi-Tebessa, 12000 Tebessa, Algeria

2 FESSNL. Biology of Living Beings Department, University Larbi Tbessi.Tebessa, 12000 Tebessa, Algeria

3 INATAA, University of Constantine 1, Constantine, Algeria

4 Laboratory of Water and Environment, University Larbi Tbessi, 12000 Tebessa, Algeria

The same reports were made by other authors who have shown that high blood pressure promotes the risk of various cardiovascular diseases (Flint et al. 2019; Rapsomaniki et al. 2014; Whelton et al. 2017), such as strokes, coronary heart disease, heart failure, fibrillation atrial (Angeli et al. 2014), and peripheral vascular diseases. HBP is considered the main risk factor for mortality in the world, and according to the WHO, it is responsible for 7.5 million deaths per year, which represents 12.8% of all deaths (WHO 2009). For 2025, researchers have estimated that 29.2% of the adult population will be hypertensive, or 1.56 billion people, for an increase of 60% in 25 years. So it seems that hypertension is a major public health problem all over the world (Kearney et al. 2005). Body mass index (BMI) has become the most widely used index to evaluate overweight and obesity. Some authors identify a new phenotype of metabolically healthy obese who lack the usual cardiometabolic risk factors of the obese subject (Disse 2014; Boirie et al. 2016). Others find that BMI is losing interest in older people. Beyond age 75, the increase in BMI is protective and no longer appears to be an independent risk factor for mortality (Stevens et al. 1998). However, this finding does not corroborate with other studies that have shown that increasing BMI in the elderly is not automatically a protective factor (Osher and Stern 2009). The metabolic disorders of obesity were then attributed to the android distribution of fat rather than to the overall corpulence (Kang et al. 2011; Oppert 2003; Vague 1956). Nonetheless, the link between android fat deposition and its association with cardiovascular risk has recently been disputed (Sari et al. 2019). A lot of attention worldwide use has also been made of the use of waist circumference (WC) for assessment and risk management of CVD because waist circumference is strongly correlated with abdominal fat (Klein et al. 2007). Recently, the WHtR has been proposed as the best screening tool than WC and BMI for cardiometabolic risk factors in adults. Thus, anthropometric measurements evaluating abdominal fat were proposed to better predict the comorbidities of obesity, such as hypertension (Lee et al. 2008). In fact, in the context of large-scale epidemiological studies and in the absence of possible measurement of blood pressure, this possible anthropometric measurement would be a simple, inexpensive, and effective asset to detect people at high risk of hypertension. In fact, in the context of large-scale epidemiological studies and in the absence of possible measurement of blood pressure, this possible anthropometric measurement would be a simple, inexpensive and effective asset to detect people at high risk of hypertension according to their BMI, WC and WHtR. It is in this perspective that we conducted this study which aimed to analyze the associations between different anthropometric measures and hypertension in an Algerian population composed of overweight, obese, and normal weight adults.

Methods and materials

This retrospective analytical study was conducted between 2013 and 2015 in a population of adults coming for consultation in different medical centers for health problems related to the metabolic profile in Tebessa, a city in eastern Algeria. A total of 900 subjects aged 18 to 92 years were invited to participate in the study, including 785 (529 women and 256 men) having complete data on hypertension, diabetes and dyslipidemia, sex, and age, and the three anthropometric indices (BMI, WC, WHtR) were included in the analyses. The surveyed subjects were selected among patients coming to consultation in different sanitary sewers of the city of Tebessa (Polyclinic Bachir Mentouri, Polyclinic Skanska, Laboratory of Biochemical Analyses (Dr. Brahmi), Hospital Establishment Bouguerra Boulaares Bekkaria, Tebessa). We included in this study any person aged 18 and over coming in consultation in different care centers and having agreed to participate in our study regardless of gender. Excluded were those who refused to participate, those who did not want to take a blood sample those who refused to make anthropometric measurements (weight, height, and waist circumference), and pregnant women. We also excluded anyone who was unable to understand and answer our questions (very sick subjects, etc.). A standardized questionnaire was used to collect information on age, sex, physical activity, personal and family history, tobacco consumption, medical history, socioeconomic level, and education level. The subjects surveyed were subdivided into five age groups by sex in order to study the prevalence of hypertension according to these two unchangeable variables.

Measurements of height and weight were carried out by students who were trained in precise measurement techniques. Height and weight were measured in lightweight clothing without shoes using a standardized WHO protocol. The weight was measured on a scale "TIAN SHAN-2003A" measuring its capacity of 180 kg (396 Ib), its accuracy is 100 g for a kg, and each subject must remove the jacket and shoes, stand upright and straight on the scale. The height of the subjects (without shoes) was measured to the nearest 0.1 cm with a portable stadiometer. BMI (kg/m^2) was calculated by dividing the weight by height squared. The WC was measured with a flexible measuring tape at a level midway between the lowest coastal margin and the iliac crest at the end of a normal exhalation. WHtR was calculated as WC (in cm) divided by height (in cm). We referred to the World Health Organization (WHO) criteria for defining the weight status of patients (WHO 2000).

Two consecutive readings of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken to obtain a mean value that was used in this study. A rest of 10 min was granted to the subjects surveyed before the blood pressure was taken. The blood pressure was measured by an automatic blood pressure monitor “OMRON M3.” Diagnosis of arterial hypertension was retained if the systolic and diastolic arterial pressure was higher than or equal to 140/90 mmHg or if the patient was already known to be hypertensive or under treatment with antihypertensive medication (Mancia et al. 2013). A blood sample was taken for the assay of biochemical parameters, total cholesterol, triglycerides, LDL cholesterol, HDL cholesterol, and blood glucose.

The data were captured and analyzed using the SPSS software version 25. In the descriptive study, we calculated simple frequencies and relative frequencies for qualitative variables and means and standard deviations for quantitative variables. In the analytical study, the ANOVA was used to compare the averages of the three quantitative variables with a normal distribution. The chi-square test was used for the qualitative variables for the comparison between the percentages. The link between two quantitative variables was studied by the Pearson correlation coefficient. Receiver operating characteristic (ROC) curves were established for anthropometric parameters (weight, BMI, TT, and RTT) to distinguish between hypertensive and non-hypertensive patients. We used the cutoff value of the variable that had the best “sensitivity-specificity” pair. This value corresponded to the point of the ROC curve closest to the point having the coordinates ($x = 0$, $y = 1$). All the subjects interviewed agreed to participate in this study. Those who did not agree were dropped from the study.

All the analyses were carried out in laboratories approved by the Algerian state by respecting the laws of the official newspaper of the Algerian Republic No. 35 of August 15, 1990. The study was approved by the Regional Ethics Committee for Algerian state. A verbal consent was obtained from each participant. All methods were applied in accordance with relevant guidelines and regulations. In all statistical tests, the cutoff of significance was set at 0.05.

Results

The final study sample consisted of 785 participants (529 (67.4%) women and 256 (32.6%) men with a median age of 47.17 ± 16.36 years (46.4 ± 16 years in women and 48.8 ± 17 years in men)). No significant difference was observed for the mean age by sex. The prevalence of hypertension was 49.7% (women 47.26%, men 55.08%, $P = 0.04$).The prevalence increased significantly by age in both males and females (Fig. 1), from 24.83% among those aged between 18 and 29 years (men 34.09%; women 20.95%) up to 78.75% among those aged 70 and over (men 81.08%; women 76.74%). Men had significantly higher mean SBP and DBP than women (systolic 131.2 versus 126.9 mmHg, $P = 0.009$; diastolic 78.0 versus 75.2 mmHg, $P = 0.008$). No significant difference was observed between hypertensive men and women concerning the mean values of SBP and DSP. The

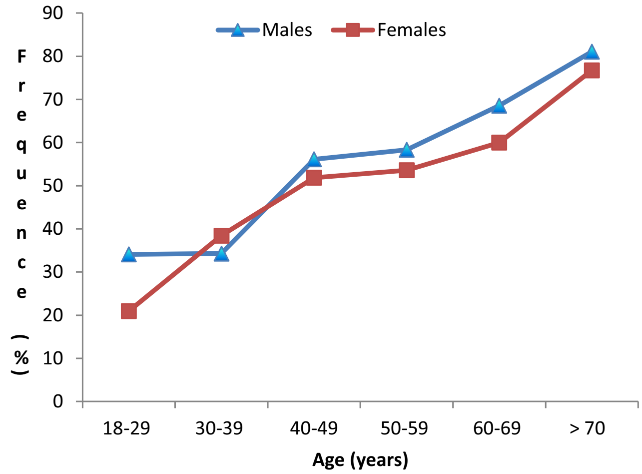

Fig. 1 Prevalence of hypertension by age and sex

comparison of hypertensive subjects with non-hypertensive subjects revealed statistically significant differences in the clinical and anthropometric indices between the two groups. The anthropometric data for hypertensive vs. non-hypertensive were the following: BMI, 29.08 ± 5.54 (kg/m^2) vs. 27.71 ± 5.5 (kg/m^2); WC, 100.3 ± 16.9 cm vs. 96.8 ± 16.1 cm; and WHtR, 0.60 ± 0.10 vs. 0.58 ± 0.10. The clinical data were the following: SBP (mmgH), 145.0 ± 17.4 vs. 111.76 ± 8.99; DBP (mmgH), 83.9 ± 12.3 vs. 68.31 ± 9.46; TC (g/l), 1.88 ± 0.48 vs. 1.79 ± 0.46; and TG (g/l) 1.39 ± 0.61 vs. 1.29 ± 0.57 (Table 1).

A positive correlation was observed between BMI and SBP, BMI, DBP, and waist circumference ($r = 0.11$, $P = 0.03$). Mean age was 52.4 years and 42 years, respectively, among hypertensive and non-hypertensive ($P < 0.0001$).

Descriptive information of normal weight, overweight, and obese is shown in Table 2.Obese had a higher mean weight, WC, WHtR, SBP, DBP, FG, TC, and TG than overweight and normal weight. The results are respectively in normal weight group, overweight group, and obese group: weight (kg), 62.49 ± 7.57 vs. 76.42 ± 8.23 vs. 92.36 ± 13.24; WC (cm), 85.82 ± 11.28 vs. 97.33 ± 11.68 vs. 110.69 ± 15.4; WHtR, 0.51 ± 0.06 vs. 0.58 ± 0.07 vs. 0.67 ± 0.09; SBP (mmHg), 124.68 ± 21.83 vs. 128.21 ± 21.65 vs. 131.55 ± 20.97; DBP (mmHg), 73.37 ± 13.95 vs. 76.78 ± 13.72 vs. 77.86 ± 12.44; FG (g/l), 1.08 ± 0.5 vs. 1.11 ± 0.43 vs. 1.24 ± 0.58; TC (g/l), 1.7 ± 0.42 vs. 1.81 ± 0.45 vs. 1.97 ± 0.48; and TG (g/l), 1.18 ± 0.55 vs. 1.35 ± 0.52 vs. 1.47 ± 0.65. The prevalence of hypertension and diabetes was higher in obese than overweight and normal weight. The hypertension data were the following: 56.69% vs. 49.80% vs. 41.94%. For diabetes data were the following: 40.82% vs. 34.18 vs. 25%. The prevalence of obesity was higher in women than in men (40.45% vs. 27.34%, $P = 0.001$) (Fig. 2). The prevalence of hypertension increased significantly with BMI from 41.94% among normal weight to 49.8% among overweight to 56.69% among obese ($P = 0.003$). When the BMI increases, the prevalence of

Table 1 Anthropometric and clinical characteristics of hypertensive and non-hypertensive subjects

.	Hypertensive ($n = 391$)	Non-hypertensive ($n = (394)$	P
Age (years)	44.73 ± 19.62	42.47 ± 15.1	$< 10^{-3}$
Weight (kg)	79. 9 ± 16.3	75.7 ± 15.3	$< 10^{-3}$
Height (m)	1.65 ± 0.08	1.65 ± 0.07	0.647
BMI (kg/m^2)	29.08 ± 5.54	27.71 ± 5.5	0.001
WC (cm)	100.3 ± 16.9	96.8 ± 16.1	0.003
WHtR	0.60 ± 0.10	0.58 ± 0.10	0.007
SBP (mmgH)	145.0 ± 17.4	111.76 ± 8.99	$< 10^{-3}$
DBP (mmgH)	83.9 ± 12.3	68.31 ± 9.46	$< 10^{-3}$
FG (g/l)	1 .18 ± 0.55	1.11 ± 0.48	0.079
TC (g/l)	1.88 ± 0.48	1.79 ± 0.46	0.007
TG (g/l)	1.39 ± 0.61	1.29 ± 0.57	0.018
Diabetes (%)	30.95	19.04	$< 10^{-3}$
Smoking			
Yes (%)	14.07	9.41	0.041
No (%)	85.93	90.59	

BMI, body mass index; WC, waist circumference; WHtR, waist circumference-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; TC, total cholesterol; TG, triglycerides

Average and standard deviations of measurements are shown. Percentages of prevalence of diabetes and consumption smoking were shown

hypertension increases significantly. We conclude that the prevalence of HBP is significantly higher in obese people than in overweight and normal weight (Fig. 3). The findings remained the same after adjusting for sex. However, hypertensive women are significantly more obese than men (0.026). Our results showed that obesity increased the risk of hypertension by a factor of 1.54 (95% CI [1.15, 2.06], $P = 0.004$).

The Pearson correlation for the association between anthropometric indicators and each of SBP and DBP is presented in Table 3. For total population, BMI was positively correlated with SBP and DBP, respectively. However, WC and WHtR were significantly correlated with SBP. No significant correlation was found between WC, WHtR and DBP. According to the BMI group, Pearson's correlation data analysis showed

Table 2 Anthropometric and clinical characteristics of the population studied according to the body mass index

.	Total ($n = 785$)	Normal BMI ($n = 248$)	Overweight ($n = (253)$	Obesity ($n = 284$)	P
Age (years)	47.17 ± 16.36	44.73 ± 19.62	48.47 ± 15.72	48.15 ± 13.33	0.017
Weight (kg)	77.79 ± 15.95	62.49 ± 7.57	76.42 ± 8.23	92.36 ± 13.24	$< 10^{-3}$
Height (m)	1.65 ± 0.08	1.66 ± 0.08	1.66 ± 0.07	1.63 ± 0.08	$< 10^{-3}$
WC (cm)	98.53 ± 16.59	85.82 ± 11.28	97.33 ± 11.68	110.69 ± 15.4	$< 10^{-3}$
WHtR	0.59 ± 0.10	0.51 ± 0.06	0.58 ± 0.07	0.67 ± 0.09	$< 10^{-3}$
Hypertension (%)	49.7	41.94	49.80	56.69	0.003
SBP (mmgH)	128.3 ± 21.62	124.68 ± 21.83	128.21 ± 21.65	131.55 ± 20.97	0.001
DBP (mmgH)	76.09 ± 13.46	73.37 ± 13.95	76.78 ± 13.72	77.86 ± 12.44	$< 10^{-3}$
FG (g/l)	1.15 ± 0.52	1 .08 ± 0.5	1.11 ± 0.43	1.24 ± 0.58	$< 10^{-3}$
TC (g/l)	1.83 ± 0.47	1.7 ± 0.42	1.81 ± 0.45	1.97 ± 0.48	$< 10^{-3}$
TG (g/l)	1.34 ± 0.59	1.18 ± 0.55	1.35 ± 0.52	1.47 ± 0.65	$< 10^{-3}$
Diabetes (%)	24.97	25	34.18	40.82	0.065
Smoking					
Yes (%)	11.73	39.13	23.91	36.96	0.127
No (%)	88.27	30.64	33.38	35.98	

BMI, body mass index; WC, waist circumference; WHtR, waist circumference -to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; TC, total cholesterol; TG, triglycerides

Average and standard deviations of measurements are shown. Percentage of prevalence of diabetes and consumption smoking were shown

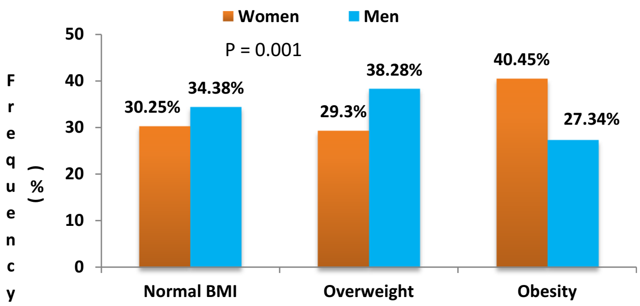

Fig. 2 Prevalence of obesity and overweight by gender of subjects surveyed

that there was no relationship between SBP and anthropometric parameters (BMI, WC, and WHtR). Only DBP was negatively associated with WHtR in overweight group ($r = -0.151$, $P = 0.015$ (Table 3).Given the continuous and quantitative characteristics of weight, BMI, WC, and WHtR, we realized ROC curves for each anthropometric parameter in order to evaluate its association with arterial hypertension. All these parameters had areas under the curve between 0.409 and 0.618. Their contributions were thus low (Table 4). The cutoff value of anthropometric WHtR parameters associated with the risk of hypertension was higher among women than men regardless of the BMI group considered. Table 5 illustrates the cutoff values, sensitivities, and specificities of the different anthropometric indices. For normal BMI group, weight cut points were 61.2 kg, 59.5 kg for women (54% sensitivity, 45% specificity) and 66.05 kg for men (45% sensitivity, 44% specificity); BMI cut points were 22 kg/m^2, 22 kg/m^2 for women (54% sensitivity, 54% specificity) and 22 kg/m^2 for men (55% sensitivity, 53% specificity); WC cut points were 85.5 cm, 85.5 cm for women (62% sensitivity, 62% specificity) and 84.5 cm for men (50% sensitivity, 46% specificity); and WHtR cut points were 0.52, 0.52 for women (62% sensitivity, 61% specificity) and 0.50 for men (55% sensitivity, 59% specificity).

For overweight group, weight cut points were 76.8 kg, 73.6 kg for women (52% sensitivity, 50% specificity) and 80.5 kg for men (61% sensitivity, 56% specificity); BMI cut points were 27 kg/m^2, 27 kg/m^2 for women (52% sensitivity, 52% specificity) and 27 kg/m^2 for men (56% sensitivity, 52% specificity); WC cut points were 99.5 cm, 95.5 cm for women (46% sensitivity, 50% specificity) and 99.5 cm for men (60% sensitivity, 56% specificity); and WHtR cut points were 0.59, 0.61 for women (47% sensitivity, 52% specificity) and 0.58 for men (54% sensitivity, 52% specificity).

For obese group, weight cut points were 90 kg, 90 kg for women (48% sensitivity, 57% specificity) and 95 kg for men (50% sensitivity, 58% specificity); BMI cut points were 33 kg/m^2, 33 kg/m^2 for women (52% sensitivity, 55% specificity) and 33 kg/m^2 for men (47% sensitivity, 55% specificity); WC cut points were 110 cm, 110 cm for women (48% sensitivity, 49% specificity) and 110 cm for men (39% sensitivity, 46% specificity); and WHtR cut points were 0.68, 0.69for women (52% sensitivity, 51% specificity) and 0.64for men (45% sensitivity, 46% specificity).

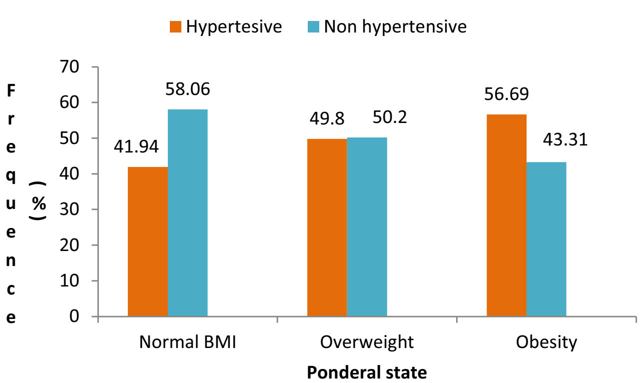

Fig. 3 Prevalence of obesity and overweight among hypertensive and non-hypertensive subjects surveyed

Table 3 Pearson's correlation coefficients between anthropometric parameters and blood pressure in normal BMI, overweight, and obese

	SBP (mmHg)	DBP (mmHg)
Correlation coefficient (*r*)		
Total population		
BMI (kg/m^2)	0.127**	0.140**
WC (cm)	0.088*	0.066
WHtR	0.088*	0.051
Normal BMI group		
BMI (kg/m^2)	0.064	0.119
WC (cm)	0.09	0.07
WHtR	0.121	0.081
Overweight group		
BMI (kg/m^2)	0.1	0.07
WC (cm)	0.013	0.087
WHtR	0.021	−0.151*
Obese group		
BMI (kg/m^2)	0.007	0.026
WC (cm)	0.024	0.031
WHtR	0.028	0.048

*$P < 0.05$

**$P < 0.001$

BMI, body mass index; WC, waist circumference; WHtR, waist circumference-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure

The table presents the values of the correlation coefficient (*r*). When the difference is significant, the value is accompanied by the the symbol *

Discussion

Hypertension is one of the main health problems in the world. A better understanding of anthropometric risk factors and their

Table 4 Areas under the ROC curve of different anthropometric parameters distinguishing hypertensive patients from normotensive patients according to their BMI

	Weight			BMI			WC			WHtR		
	AUC	95% CI	*P*	AUC	95% CI	*P*	AUC	95% CI	*P*	AUC	95% CI	*P*
Normal BMI	0.506	0.431–0.58	0.882	0.561	0.489–0.632	0.102	0.567	0.495–0.640	0.07	0.575	0.502–0.648	0.045
Women	0.514	0.420–0.608	0.758	0.552	0.451–0.642	0.27	0.609	0.518–0.701	0.019	0.605	0.513–0.697	0.024
Men	0.470	0.345–0.595	0.633	0.577	0.457–0.696	0.218	0.498	0.377–620	0.977	0.545	0.423–0.666	0.474
Overweight	0.570	0.499–0.641	0.054	0.518	0.447–0.590	0.6	0.514	0.442–0.585	0.7	0.486	0.414–0.557	0.697
Women	0.503	0.410–0.595	0.9	0.409	0.407–0.591	0.979	0.457	0.365–0.55	0.363	0.475	0.382–0.568	0.595
Men	0.618	0.506–0.731	0.045	0.542	0.426–0.659	0.472	0.588	0.472–0.704	0.136	0.555	0.438–0.672	0.348
Obesity	0.526	0.458–0.593	0.46	0.508	0.440–0.576	0.816	0.499	0.431–0.566	0.966	0.493	0.425–0.561	0.839
Women	0.507	0.429–0.584	0.864	0.533	0.455–0.610	0.411	0.514	0.436–0.592	0.723	0.528	0.451–0.605	0.48
Men	0.508	0.359–0.657	0.911	0.482	0.334–0.631	0.809	0.475	0.327–0.622	0.729	0.452	0.305–0.598	0.508

BMI, body mass index; WC, waist circumference; WHtR, waist circumference-to-height ratio; AUC, area under the curve; 95% CI, 95% confidence interval

All area under the curve was presented for each parameter. The lower and upper bounds of the confidence interval are mentioned

correlations was the priority. Given the results mentioned in this study, our work aimed to determine the relationship between blood pressure and anthropometric indices (using WC, WHtR, and BMI as indicators) in adult Algerian subjects. In our study as in other studies, the risk of hypertension increased with age (Tazi et al. 2009; Dua et al. 2014). Blood pressure increases with age. Indeed, aging promotes the loss of elasticity of the arteries. The prevalence of hypertension in our study was higher than that of other studies 49.7% vs. 44.8% (Ho Anh Hien et al. 2018). However, time differences in blood pressure (BP) visits, BP measurement methods, sample size, age of subjects examined, ethnicity, socioeconomic status, and differences in geographic areas between studies make it difficult to compare the results. Nevertheless, several studies have suggested that blood pressure is a common health problem. In this study, the prevalence of hypertension was significantly higher among men as compared with women as in other studies (Everett and Zajacova 2015, Choi et al. 2017, Ho Anh Hien et al. 2018).

The study demonstrated that among Algerian adults, the presence of abdominal obesity is a risk factor for hypertension. The positive association observed in our study between waist circumference and hypertension has been reported in other studies (Bose et al. 2003; Huang et al. 2007). Abdominal obesity has been recognized as a risk factor for CVD. Many health risks have been linked to abdominal obesity including diabetes, hypertension, cardiovascular disease, arthritis, respiratory disease, breast cancer, ovarian dysfunction, menstrual irregularities, and bad social image (Onuoha et al. 2016). Abdominal obesity, assessed by the waist measurement (WC), has been shown to better predict the risk of these long-term cardiometabolic complications. The waist

Table 5 Cutoff, sensitivities, and specificities of anthropometric indices in the prediction of high blood pressure

	Weight			BMI			WC			WHtR		
	Seuil (kg)	Se(%)	Sp (%)	Seuil (kg/m^2)	Se (%)	Sp (%)	Seuil (cm)	Se (%)	Sp (%)	Seuil	Se (%)	Sp (%)
Normal BMI	61.2	50	44	22	55	52	85.5	54	57	0.52	57	56
Women	59.5	54	45	22	54	54	85.5	62	62	0.52	62	61
Men	66.05	45	44	22	55	53	84.5	50	46	0.5	55	59
Overweight	76.8	57	59	27	51	52	99.5	52	52	0.59	48	45
Women	73.6	52	50	27	52	52	95.5	46	50	0.61	47	52
Men	80.5	61	56	27	56	52	99.5	60	56	0.58	54	52
Obesity	90	52	56	33	50	50	110	46	48	0.68	49	52
Women	90	48	57	33	52	55	110	48	49	0.69	52	51
Men	95	50	58	33	47	55	110	39	46	0.64	45	46

Cutoff of sensitivities and specificities was presented for each index and each sex

BMI, body mass index; WC, waist circumference; WHtR, waist circumference-to-height ratio; Se, sensitivity; Sp, specificity.

circumference of overweight and obese categories were significantly ($P < 0.0001$) higher than the normal weight category. The two measures together, WC and BMI, are even better predictors of these diseases if they are combined. In reality, it is well shown today that it is the excess of fat mass and in particular its perivisceral or abdominal localization which is involved in this predisposition to cardiometabolic complications (Pataky et al. 2009). The relationship between obesity and arterial hypertension has been documented in the literature (Cambien 1982; Gebel 2011; Praso et al. 2012). This study confirmed the relationship between obesity and arterial hypertension since its prevalence is significantly higher in obese than overweight and normal weight. The same findings were reported by Longo-Mbenza et al. (2007). On the other hand, our study has shown that DBP and SBP were positively correlated to the BMI. Results of a study conducted in Serbia by Pantelinac (2007) showed that systolic and diastolic blood pressures are significantly associated with BMI. According to the results of a study conducted in Morocco, Tazi et al. (2009) showed that the risk increased with increased body mass index, waist circumference, and hypercholesterolaemia. In Tunisia, researchers have shown in 5802 subjects that obesity is an important risk factor for the development of hypertension (Boujnah et al. 2018). Some studies suggest that the association between obesity and blood pressure could be explained by a mechanism related to the variation in the amount of abdominal fat estimated by a single clinical parameter waist circumference. Among the obese in this study, 87.32% had abdominal obesity. Our results also showed that WC and WHtR were significantly correlated with SBP. In this study, the prevalence of obesity is significantly higher in women than in men, but the prevalence of arterial hypertension is higher in obese men than in obese women. Several studies have reported a high prevalence of female obesity in relation to men in both urban and rural settings (Otang-Mbeng et al. 2017; Rheeder et al. 2017). The WC cutoff points corresponding to BMI values of 25 kg/m^2 were 99.5 cm in men and 95.5 cm in women. When the BMI is greater than or equal to 30 kg/m^2, the cut points were 110 cm in both men and women. In this study, a positive correlation was found between BMI and WC, $r = 0.716$, $P < 0.0001$. Taking into consideration gender, we found a linear and higher correlation between BMI and WC in men than in women. Another study carried out in Tunisia showed WC cutoff for a BMI equal to 25 kg/m^2 lower than those found in this study for both men and women 85 cm and 79 cm, respectively (Bouguerra et al. 2007).

Second, we concluded that all the anthropometric parameters studied were equal in terms of HTA identification in all three groups. Threshold values of anthropometric parameters to distinguish between hypertensive patients and non-hypertensive patients, regardless of their BMI, were not very sensitive or very specific. As a result, in emerging countries such as Algeria, anthropometry could not be an interesting public health asset in the detection of hypertension in people with normal BMI as in the overweight and/or obese. The same findings were shown by Sebai et al. (2018) in patients with type 2 diabetes. Other studies have shown that WHtR has performed better than BMI and WC for the association with hypertension and diabetes (Cai et al. 2013). Third, the BMI cutoff associated with the presence of hypertension in normal BMI, overweight, and obese subjects was equal among men and women in each BMI group. No significant association was observed. In this study, we have more women than men, and this is a limitation of this work. The high number of women is due to their significant presence in the places where the survey is conducted. This may explain some results obtained in this investigation.

Conclusions

In this study, blood pressure is significantly linked to obesity, suggesting the role of weight loss in the treatment of hypertension in overweight and/or obese people. In addition, unlike the data in the literature, the discriminating power of anthropometry in predicting HTA is limited or absent regardless of the value of BMI. Its interest in epidemiological studies in developing countries would therefore be modest. Studies at the national level are necessary to support the validity of our results and to identify specific references to the Algerian population while taking into account the overweight.

Acknowledgments We thank all the subjects who participated in this study and the medical staff who helped us for the realization of the biochemical analyzes.

Author contributions Taleb S was responsible for the study design; K Boulaba, A Yousfi, N Taleb, B Difallah, and S Negrichi participated in data collection and biochemical analyses. Taleb S analyzed the data and was involved in the interpretation. All authors critically read the drafts of this paper and approved its final version prior to submission for publication.

Funding information This work was supported by the National Fund for Scientific Research to Pr. F. BAALI (Laboratory of Water and Environment), the Ministry of High Education and Scientific Research of Algeria (PRFU Project D01N01UN120120180002).

Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (NCC2014-0068) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was required.

References

Angeli F, Reboldi G, Verdecchia P (2014) Hypertension, inflammation and atrial fibrillation. J Hypertens 32:480. https://doi.org/10.1097/HJH.0000000000000112

Boirie Y, Farigon N, Miolanne M, Montel F, Lahaye C, Guillet C et al (2016) Sarcopenic obesity: causes and consequences. Cah Nutr Diet 51(3):132–138. https://doi.org/10.1016/j.cnd.2015.12.002

Bose K, Ghosh A, Roy S, Gangopadhyay S (2003) (2003). Blood pressure and waist circumference: an empirical study of the effects of waist circumference on blood pressure among Bengalee male jute mill workers of Belur, West Bengal, India. J Physiol Anthropol Appl Hum Sci 22(4):169–173. https://doi.org/10.2114/jpa.22.169

Bouguerra R, Alberti H, Smida H, Salem LB, Rayana CB, El Atti J et al (2007) Waist circumference cut-off points for identification of abdominal obesity among the Tunisian adult population. Diabetes Obes Metab 9(6):859–868. https://doi.org/10.1111/j.1463-1326.2006.00667.x

Boujnah R, Laila Nazek L, Maalej M, Youness ELAchhab Y, Nejjari C (2018) Hypertension in Tunisian adults attending primary care physicians (ETHNA-Tunisia). Indian Heart J 70(4):544–547. https://doi.org/10.1016/j.ihj.2017.11.005

Cai L, Liu A, Zhang Y, Wang P (2013) Waist-to-height ratio and cardiovascular risk factors among Chinese adults in Beijing. PLoS ONE 8(7):e69298. https://doi.org/10.1371/journal.pone.0069298

Cambien F (1982) Relationship between obesity and arterial hypertension. Nouv Press Med 11(49):3641–3646 www.ncbi.nlm.nih.gov›pubmed

Choi HM, Kim HC, Kang DR (2017) Sex differences in hypertension prevalence and control: analysis of the 2010-2014 Korea National Health and Nutrition Examination Survey. PLoS One 12:e0178334. https://doi.org/10.1371/journal.pone.0178334

Disse E (2014) Anciennes mesures – nouveaux phénotypes. In: JABD 2014: Journée annuelle Benjamin Delessert. CNIT – Paris-La-Défense

Dua S, Bhuker M, Sharma P, Dhall M, Kapoor S (2014) (2014). Body mass index relates to blood pressure among adults. N Am J Med Sci 6(2):89–95. https://doi.org/10.4103/1947-2714.127751

Everett B, Zajacova A (2015) (2015). Gender differences in hypertension and hypertension awareness among young adults. Biodemogr Soc Biol 61(1):1–17. https://doi.org/10.1080/19485565.2014.929488

Flint AC, Conell C, Ren X et al (2019) Effect of systolic and diastolic blood pressure on cardiovascular outcomes. N Engl J Med 381:243. https://doi.org/10.1056/NEJMoa1803180

Gebel E (2011) The problem of pounds. The parallel paths of obesity and type 2 diabetes. Diabetes Forecast 64(9):35–37. https://doi.org/10.1016/j.jpeds.2007.08.037

Hien HA, Tam NM, Tam V, Derese A, Dirk Devroey D (2018) Prevalence, awareness, treatment, and control of hypertension and its risk factors in (Central) Vietnam. Int J Hypertens 2018:6326984, 12 pages. https://doi.org/10.1155/2018/6326984

Huang XB, Hu R, Liu JL, Hou YL, Le QR LKL, Lu XE, She Q, Yin YH, Lan XB (2007) Relationship between body mass index, waist circumference and blood pressure among 5246 residents in Chongqing area. Zhonghua Xin Xue Guan Bing Za Zhi 35(7):655–658 34(28):2159–219,

Kang SM, Yoon JW, Ahn HY, Kim SY, Lee KH et al (2011) Android fat depot is more closely associated with metabolic syndrome than abdominal visceral fat in elderly people. PLoS ONE 6(11):e27694. https://doi.org/10.1371/journal.pone.0027694

Kearney PM, Whelton M, Reynolds K et al (2005) Global burden of hypertension: analysis of worldwide data. Lancet 365:217–223. https://doi.org/10.1016/S0140-6736(05)17741-1

Klein S, Allison DB, Heymsfield SB, Kelley DE, Leibel RL et al (2007) Waist circumference and cardiometabolic risk: a consensus statement from Shaping -America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. Am J Clin Nutr 85:1197–1202. https://doi.org/10.1093/ajcn/85.5.1197

Lee CMY, Huxley RR, Wildman RP, Woodward M (2008) Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol 61(7):646–653. https://doi.org/10.1016/j.jclinepi.2007.08.012

Longo-Mbenza B, Nkoy Belila J, Vangu Ngoma D, Mbungu S (2007) Prevalence and risk factors of arterial hypertension among urban Africans in workplace: the obsolete role of body mass index. Niger J Med 16(1):42–49. [Ref list]. https://doi.org/10.4314/njm.v16i1.37280

Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, Böhm M et al (2013) ESH/ESC Guidelines for the management of arterial hypertension. The Task Force for the management of arterial hypertension of the European Society of Hyper-tension (ESH) and of the European Society of Cardiology (ESC). Eur Heart North Am J Med Sci 2014 6(2). https://doi.org/10.1097/01.hjh.0000431740.32696.cc

Onuoha FM, Ebirim CC, Ajonuma BC et al (2016) Correlation between central obesity and blood pressure in an adult Nigerian population. J Insulin Resist 1(1):a16. https://doi.org/10.4102/jir.v1i1.16

Oppert J-M (2003) Obesity: what measures for "phenotypes" at cardiovascular risk? Sang Thrombose Vaiss 15(9):6

Osher E, Stern N (2009) Obesity in elderly subjects: in sheep's clothing perhaps, but still a wolf! Diabetes Care 32(Suppl 2):S398–S402. https://doi.org/10.2337/dc09-S347

Otang-Mbeng W, Otunola GA, Afolayan AJ (2017) Lifestyle factors and co-morbidities associated with obesity and overweight in Nkonkobe Muni-cipality of the Eastern Cape, South Africa. J Health Popul Nutr 36:22. https://doi.org/10.1186/s41043-017-0098-9

Pantelinac P (2007) Nutricija, tretman i kardiovaskularni faktori rizika sa međunarodno prihvaćenim preporukama za prevenciju ateroskleroze. Novi Sad: Društvo fiziologa Srbije;. Ishrana i njen značaj u lečenju šećerne bolesti; pp. 121–131. [Google Scholar] [Ref list].

Pataky Z, Bobbioni HE, Makoundou V, Golay A (2009) Périmètre abdominal augmenté et facteurs de risqué cardiovasculaire. Rev Med Suisse 5:617–615 www.revmed.ch›RMS›RMS-196›Perimetre-abdom

Praso S, Jusupovic F, Ramic E, Gledo I, Ferkovic V, Novakovic B et al (2012) Obesity as a Risk Factor for Artherial Hypertension. Mater Soc 24(2):87–90. https://doi.org/10.5455/msm.2012.24.87-90

Rapsomaniki E, Timmis A, George J et al (2014) Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 1·25 million people. Lancet 383:1899. https://doi.org/10.1016/S0140-6736(14)60685-1

Rheeder P, Morris-Paxton AA, Ewing R-MG, Woods D. (2017). The noncommunicable disease outcomes of primary healthcare screening in two rural subdistricts of the Eastern Cape Province, South Africa. Afr J Prim HealthCare Fam Med;9(1) [Internet, cited 23 June 2018] Available on ttps://www.ncbi.nlm.nih.gov/pmc/articles/PMC5675926/. doi: https://doi.org/10.4102/phcfm.v9i1.1466

Sari CI, Eikelis N, Head GA, Schlaich M, Meikle P, Lambert G, Lambert E (2019) Android fat deposition and its association with cardiovascular risk factors in overweight young males. Front Physiol 10:1162. https://doi.org/10.3389/fphys.2019.01162

Sebai I, Oueslati I, Abdessalema H, Yazidi M, Chaker F, Grira W, Amrouche C, Chihaoui M (2018) Links between anthropometric parameters and hypertension in Tunisian patients with type 2 diabetes mellitus. Nutr Clin Metab. https://doi.org/10.1016/j.nupar.2018.10.003

Stevens J, Cai J, Pamuk ER, Williamson DF, Thun MJ, Wood JL (1998) The effect of age on the association between body mass index and mortality. N Engl J Med 338(1):1–7. https://doi.org/10.1056/NEJM199801013380101

Tackling G, Borhade MB (2019) Hypertensive Heart Disease. Treasure Island (FL): StatPearls Publishing. www.ncbi.nlm.nih.gov›NBK539800

Tazi, M.A, Abir-Khalil, S, Lahmouz F, Arrach M.L. and Chaouki N. (2009). Risk factors for hypertension among the adult Moroccan population. Eastern Mediterr Health J | Past issues | Volume 15, 2009 | Volume 15, issue 4. *V* www.emro.who.int › risk-factors-for

Vague J (1956) The degree of masculine differentiation of obesities: a factor deter-mining predisposition to diabetes, atherosclerosis, gout, and uric calculous disease. Am J Clin Nutr 4(1):20–34. https://doi.org/10.1093/ajcn/4.1.20

Visscher TL, Seidell JC (2001) The public health impact of obesity. Annu Rev Public Health 22:355–375. https://doi.org/10.1146/annurev.publhealth.22.1.355

Whelton PK, Carey RM, Aronow WS et al (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: a report of the American College of Cardiology/American Heart Association Task Force on clinical practice guidelines. Hypertension 2018 71:e13. https://doi.org/10.1161/HYP.0000000000000066

WHO (2000) Obesity: preventing and managing the global epidemic. Report of a WHO Consultation (WHO Technical Report Series 894), 252 pages. www.who.int›WHO_TRS_894

WHO (2018) Obesity and overweight. World Health Organization February, Geneva https://www.who.int/fr/news-room/fact-sheets/detail/obesity-and-overweight

WHO (World Health Organisation (2019). Hypertension. www.who.int. Consulted on 28/05/2020

World Health Organization (2009). Global health risks: mortality and burden of disease attributable to selected major risks, http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf