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Which anthropometric measurements is most closely related to elevated blood pressure?

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Background. Epidemiological studies find a progressive increase in the prevalence of elevated blood pressure with increasing adipose tissue. But there is no common opinion about which effectiveness of the anthropometric measurement tools indicating general or android obesity are most important to follow up in patients with elevated blood pressures.

Objectives. To identify which anthropometric measurements are most closely related to blood pressure elevation.

Methods. A cross-sectional descriptive study of 1727 subjects [894 (50.6%) men and 833 (48.2%) women, aged 18–65 years old] was held in Edirne, Turkey. Each subject's weight, height, waist and hip circumference, triceps skin fold and blood pressures was measured; waist to hip ratio and body mass index were calculated. The relations between blood pressure and different anthropometric variables in both genders were investigated in linear regression models.

Results. The mean systolic and diastolic blood pressures were 123.49 ± 17.60 and 78.79 ± 10.37 mmHg. According to body mass index 23.7% of the subjects were obese (>29.9 kg/m^2). When waist circumference cut-off points were compared with waist to hip ratio the android obesity ratio was doubled (32.3% versus 16.6%). 119 subjects (6.8%) were not obese according to body mass index but nonetheless had waist circumference measurements above the cut-off points suggesting a high cardiovascular risk. In the linear regression models waist circumference was found to be an independent risk factor for blood pressure in men; however body mass was more important index and waist circumference somewhat less so for women.

Conclusion. In primary care waist circumference should be a useful tool screening for and following android obesity in patients with elevated blood pressure.

Keywords. Anthropometric measurements, blood pressure, obesity, primary care, Turkey.

Introduction

Epidemiological studies have found a progressive increase in the prevalence of elevated blood pressure with increasing adipose tissue.[1] Both obesity and hypertension are common and important problems in primary care.[2] In the recent decade many prospective and cross-sectional studies have been done in order to evaluate the anthropometric measurement methods to assess patients with elevated blood pressure, which is a dominant cardiovascular risk factor.[3–8] Different anthropometric measurements like body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio, subscapular thickness or triceps skin fold (TSF) measurement as a part of index of trunk or peripheral skin folds are investigated for this purpose.[9–12] BMI (kg/m^2) is widely used for classification of overweight and obesity, but it does not account for the wide variation of the fat distributions. Therefore, there is currently overwhelming evidence android obesity (described as high proportion of abdominal fat) is a greater risk factor for cardiovascular diseases (CVD) than general obesity.[13]

Primary care physicians are confronted by a remarkable heterogeneity among their patients.[12,14] A simple question rises; which anthropometric measurements may be useful and effective to screen for the android obesity type of body fat of patients with elevated blood pressure in primary care practice? It has been recommended that every population should determine their best anthropometric measurement tool(s) in order to screen general and visceral adiposity.[6] But there is only one study related to this question in Turkey. The TEKHARF study

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(Turkish Adults Hearth Disease and Risk Factors Study) obesity is studied as an independent risk factor for CVD nationwide.[15,16] BMI was found as a strong independent marker of systolic and diastolic blood pressures (SBP, DBP) in women while in males the determinant value of the WHR was equivalent to BMI in the same study.

In this study we aimed to investigate the relations between the general and android obesity measurement tools (BMI, WC, WHR and TSF) with the SBP and DBP and to identify their effectiveness to screen patients with elevated blood pressure for android obesity in primary care.

Methods

The study design
This cross-sectional descriptive study was held between January and March 2001 in Edirne city, population of nearly 11 000, located at the borders of Bulgaria and Greece with Turkey. The population we studied were 87 143 people aged between 18–65 years living in the urban and central rural Edirne. This population was divided into 57 groups (45 urban, 12 rural) of known geographic borders and population counts. All of these groups were accepted as homogeneous. Subjects were selected randomly from these groups in numbers weighted to their population. 1936 subjects were selected by multi-stage sampling method using the population reports of local governmental health office for year 2000. None of the subjects refused the study but 12 (0.6%) pregnant and 209 subjects (10.7%) who were using an antihypertensive medication were omitted from the study. The remaining 1727 subjects were accepted as main study group. Before the study, permission of the Trakya University Ethics Committee had been granted (TÜBAP 314).

Data collection
Data collection was carried out by face-to-face interviews at the homes and worksites of subjects by two trained researchers. Demographic features, socio-economic statues, relevant personal and family history data about hypertension, smoking habits and nicotine dependency, alcohol use and dependency, frequency and intensity of regular physical exercises and physical activity level were interviewed using a questionnaire. Subjects were categorized as smokers, non-smokers, or ex-smokers regarding their tobacco usage, and as users or non-users regarding their alcohol usage. According to physical activity level the subjects were divided into four activity groups labeled as levels L1 to L4 in increasing order.

BP measurements
Every subject's BP was measured with a standardized protocol.[17,18] The subjects rested for at least 10 minutes in seated position and their arms were supported at the level of heart. All of the subjects were with light clothing (no tight clothing constricting the arm) and in optimal room conditions. At least two blood measurements at a five minutes interval was taken from the subjects from both of arms in mild flexion with an aneroid sphygmomanometer (Perfect-Aneroid sphygmomanometer, ERKA, Germany). The mean of the two readings in the higher arm side was accepted as BP. The SBP was accepted as the first Korotkoff sound phase and DBP as the fifth phase (disappearance of sounds) to nearest 2 mmHg. Three different cuff sizes were used in the subjects according to their arm circumferences as the recommendations of the British Hypertension Society criteria (standard adult = 12×26 cm, large adult = 12×40 cm, adult thigh cuff = 20×40 cm).[18] The aneroid sphygmomanometers were calibrated with a standardized mercury column manometer.

Anthropometric measurements
Every subject's height was measured in centimeters while the participant stood still without shoes and weight was measured to the nearest 0.1 kg with electronic weight scale (model 770; Seca, Germany) in kilograms with the participant lightly clothed. BMI was calculated as weight divided by square of height (kg/m^2). Subjects were categorized according to their BMI as the criteria of World Health Organization (WHO) and cut-off point for obesity is accepted as BMI > 29.9 kg/m^2. WC was measured in centimeters at the midpoint between the bottom of the ribs and the top of the iliac crest (cut-off points for cardiovascular disease risk was 102 cm for men and 88 for women defined as the criteria of WHO).[19] Hip circumference was measured at the largest posterior extension of the buttocks. WHR was calculated by dividing these two values with each other (cut-off points for cardiovascular disease risk was 1.0 in men and 0.85 in women defined as the criteria of WHO). TSF is measured in every subject when the forearm is at full extension with a Lange Caliper (Cambridge Scientific Instruments, Cambridge, MD) in the widest part of the skin fold.

Statistical analyses
All of the analyses performed using SSPS (Statistical Package for Social Sciences version 10.0). Pearson correlation test, independent samples *t*-test, one-way Anova tests were used to investigate the relations between the groups. All of the anthropometric variables were explored for their relation with SBP and DBP in univariate analyses. Then the statistically significant variables were tested in both genders with linear regression models separately. The Durbin-Watson analyses, tolerance and variance inflation factors were explored to determine for the validity of the each models. A P value of $P < 0.05$ was accepted as significant.

Table 1 *The mean values of blood pressure and anthropometric variables measured in the subjects*

	Min–max	Men	Min–max	Women
SBP (mmHg)	90–240	126.78 ± 17.03	70–210	120.02 ± 17.55
DBP (mmHg)	50–140	81.17 ± 9.82	50–120	76.23 ± 10.34
Weight (Kg)	45–128	79.68 ± 13.52	41–114	67.73 ± 12.95
Height (cm)	149–196	172.66 ± 6.94	140–186	159.68 ± 6.61
Hip (cm)	79–166	104.12 ± 8.15	63–155	104.75 ± 10.80
WC (cm)	54–142	94.95 ± 11.46	56–128	83.64 ± 12.57
WHR	0.56–8.84	0.91 ± 0.27	0.54–1.32	0.79 ± 0.07
TSF (mm)	1–35	8.64 ± 4.70	4–62	17.33 ± 7.75
BMI (kg/m^2)	15.57–46.09	26.72 ± 4.33	15.74–44.99	29.65 ± 5.35

SBP = systolic blood pressure; DBP = diastolic blood pressure; WC = waist circumference; WHR = waist to hip ratio; TSF = triceps skin fold; BMI = body mass index.

Results

General data

There were 1727 subjects [894 (50.6%) men and 833 (48.2%) women] in the study group. The mean age of the study group was 39.25 ± 11.84 (range 18–65) years, SBP was 123.49 ± 17.60 (range 70–240), and DBP was 78.79 ± 10.37 (range 50–140) mmHg. The mean SBP was 6 and DBP 5 mmHg higher in men than in women ($P < 0.001$). The SBP and DBP were correlated each in both genders (men R = 0.768, women R = 0.784, $P < 0.001$). The mean values of SBP, DBP and anthropometric measurements in each gender are represented in Table 1.

Anthropometric measurements and obesity

According to their BMI, 632 (36.5%) of the subjects were overweight, and 410 (23.7%) of them were obese. The obesity groups classified according to subjects' BMI measurements in both genders are represented in Table 2. According to WHR 277 subjects (16.6%) and to WC measurements 557 subjects (32.3%) were in relative high CVD risk groups. These classified CVD risk groups of WC and WHR in both genders are also shown in Table 3. In both genders BMI was correlated with other anthropometric measurements. For women the BMI was correlated with WC (R = 0.825), WHR (R= 0.416), TSF (R= 0.627) ($P < 0.001$) while the corresponding ratios in men were WC (R = 0.838), WHR (R = 0.209), TSF (R = 0.405) ($P < 0.001$). 96 (10.7%) men subjects had WC > 102 cm and 86 (10.3%) female subjects had WC > 88 cm when they were overweight (BMI = 24.9–29.9 kg/m^2). These ratios in obese subjects (>29.9 kg/m^2) were as follows: 42 (4.65%) men and 77 (9.2%) women subjects. However 6 men (0.6%) and 2 (0.2%) women subjects were obese although they had WC measurements below the cut-off points.

Table 2 *The BMI groups defined by the criteria of World Health Organization*

Kg/m^2	Men		Women	
Underweight (<18.5)	39	4.4%	74	8.9%
Normal (18.50–24.9)	282	31.5%	290	34.8%
Overweight (25–29.9)	383	42.8%	249	29.9%
Obesity Stage I (30–34.9)	158	17.7%	149	17.9%
Obesity Stage II (35–39.9)	26	2.9%	60	7.2%
Obesity Stage III (>40)	6	0.7%	11	1.3%
Total	894	100%	833	100%

Table 3 *The waist to hip ratio and waist circumference risk groups according to the cut-off points for relative risk of cardiovascular diseases in both genders defined by World Health Organization*

	Men	*n*	%	Women	*n*	%
WHR						
No Risk	(<0.90)	378	42.3	(<0.80)	454	54.5
Medium Risk	(0.90–1.0)	402	45.0	(0.81–0.85)	216	25.9
High Risk	(>1.0)	114	12.8	(>0.85)	163	19.6
WC						
No Risk	(<94 cm)	391	43.7	(<80 cm)	335	40.2
Medium Risk	(94–101 cm)	240	26.8	(80–87 cm)	204	24.5
High Risk	(>101 cm)	263	29.4	(>88 cm)	294	35.3

WC = waist circumference; WHR = waist to hip ratio.

The relation of the anthropometric measurements with blood pressure

In univariate analyses SBP and DBP were found to be correlated with all of the anthropometric measurements in both genders as shown in Table 4. The results of the multiple linear regression models to evaluate the effects

TABLE 4 *The partial correlation of anthropometric variables with systolic and diastolic blood pressure in both genders (Pearson correlation test)*

	SBP				DBP			
	Men		Women		Men		Women	
	R	*P*	R	*P*	R	*P*	R	*P*
WC	0.337	<0.001	0.515	<0.001	0.330	<0.001	0.455	<0.001
WHR	0.064	<0.001	0.350	<0.001	0.096	<0.001	0.272	<0.001
TSF	0.135	<0.001	0.340	<0.001	0.150	<0.001	0.320	<0.001
BMI	0.296	<0.001	0.504	<0.001	0.312	<0.001	0.475	<0.001

SBP = systolic blood pressure; DBP = diastolic blood pressure; WC = waist circumference; WHR = waist to hip ratio; TSF = triseps skin fold; BMI = body mass index.

TABLE 5 *The result of the linear regression models that representing the relation of the systolic and diastolic blood pressure with anthropometric variables in men*

	SBP					DBP				
	Unstandardized Coefficients B	*t*	*P*	95% Confidence Interval for B		Unstandardized Coefficients B	*t*	*P*	95% Confidence Interval for B	
				Lower	Upper				Lower	Upper
Constant	80.093	17.204	0.001	70.956	89.230	55.063	20.502	0.001	49.792	60.335
WC	0.450	5.176	0.001	0.279	0.620	0.193	3.845	0.001	0.094	0.291
WHR	−1.123	−0.557	0.578	−5.080	2.833	0.636	0.547	0.584	−1.646	2.919
TSF	−4.236E	−0.294	0.768	−0.325	0.240	9.417E	0.113	0.910	−0.153	0.172
BMI	0.200	0.857	0.392	−0.285	0.657	0.267	1.987	0.047	0.003	0.531

SBP = systolic blood pressure; DBP = diastolic blood pressure; WC = waist circumference; WHR = waist to hip ratio; TSF = triseps skin fold; BMI = body mass index.

of these four anthropometric parameters on SBP and DBP in each gender are shown in Tables 5 and 6. Regarding the results of these models the most important anthropometric factor in relation to the elevation in SBP and DBP was WC in men. However BMI was most important for women followed by WC. The R-square for SBP and DBP were 0.124 and 0.112 in men while 0.308 and 0.224 in women. According to these results 12% of the SBP and 11% of DBP elevation could be explained by anthropometric variables in men while 30% and 22% in women respectively.

Discussion

Summary of the findings

Overweight and obesity are major public health concerns for primary care physicians. This statement was also confirmed in this present study, as both general and android obesity is very prevalent in our subjects. Nearly a quarter of our patients had general obesity while more than half of our subjects had android obesity according to WC cut-off points.

Also according to the WC measurements cut-off points, many subjects (6.8%) might have not been identified as having android obesity, with the attendant high CVD risk because of obesity if only BMI classification of obesity is used. The WC was more important in overweight subjects. 27% of the subjects had android obesity although they were not classified as generally obese. This highlights the importance of detecting of android obesity in daily practice as these patients can be easily neglected. Similar to our results Booth *et al.*[20] have claimed that if WC is used as the criterion, the prevalence of overweight and obesity may be significantly greater than is detected by the BMI as calculated from the self-reported weight and height in the Australian adults. It is also an interesting point that WC was a more accurate android obesity measurement tool than WHR in our study. The rate of android obesity

TABLE 6 *The result of the linear regression models that representing the relation of the systolic and diastolic blood pressure with anthropometric variables in women*

	SBP					DBP				
	Unstandardized Coefficients B	*t*	*P*	95% Confidence Interval for B		Unstandardized Coefficients B	*t*	*P*	95% Confidence Interval for B	
				Lower	Upper				Lower	Upper
Constant	55.872	8.902	0.001	43.552	68.191	46.836	12.250	0.001	39.331	54.340
WC	0.320	2.807	0.005	0.096	0543	0.159	2.291	0.022	0.023	0.295
WHR	16.167	1.296	0.197	−8.315	40.648	0.189	0.025	0.980	−14.725	15.103
TSF	8.592E	0.981	0.327	−0.086	0.258	3.843E	0.721	0.471	−0.066	0.143
BMI	0.863	4.274	0.001	0.467	1.260	0.573	4.657	0.001	0.332	0.815

ratios was only half when WHR measurements are used instead of WC. Some investigators have proposed that WC is a superior indicator, because it requires only one measurement and is a better indicator of visceral fat and CVD risk than the commonly used WHR.[21–23] A seven-year longitudinal study conducted in women revealed that the change in WC was a better correlate of the change in visceral adipose tissue observed over this period than the change in WHR.[24] Misleading information may be caused by simultaneous increase in waist and hip measurements, which results in the WHR being stable over time despite considerable accumulation of visceral adipose tissue. Thus WC provides a crude index of absolute amount of abdominal adipose tissue whereas WHR provides an index of relative accumulation of abdominal fat to generalized obesity.[11]

An important portion of the increase in the SBP and DBP can be correlated with the anthropometric variables in our study group especially in women. WC was the most important variable in men but somewhat less so after the BMI in women. This highlights the importance of android obesity on blood pressure in both genders.

BMI is widely used as a measure of fatness in epidemiological studies because it has been shown that this index is highly correlated with body fat and is nearly independent of height.[10] Body composition in some of the participants in the Framingham Offspring Study also has been measured by bioelectric impedance, a more precise method of estimating body fat, and BMI, though correlated with the bioelectric impedance measurement, did not explain all variability in fatness in this population.[25] This indicates that BMI may not reflect represent body fat in all individuals. This is particularly true in men and is due to the fact that BMI is mostly a measure of weight and therefore does not discriminate between body fat and lean mass. In a recent study the answer for the question of whether the measurement of the fat distribution pattern (WHR, WC) adds strength to that of BMI alone in the prediction of elevated blood pressure was investigated.[26] There is some evidence that WC adds to the prediction of elevated blood pressure in younger subjects (<65 years) but has no effect on prediction for older patients (>65). But in the Third National Health and Nutrition Examination Survey within the same three BMI categories (18.5–24.9, 25.0–29.9, 30.0–34.9 kg/m^2) the subjects with high WC values (>102 cm) were increasingly likely to have elevated blood pressure compared with normal WC values as was found in our study.[8] However Onat *et al*.[15] have claimed that the BMI is a strong independent actor for SBP in women, and that BMI and WHR are equal importance for men in Turkish adults. These differences can be explained with the by the differences in the study population. First of all TEKHARF was a nationwide study and there are great differences in the different parts of the country. So these results can't be applied to one specific region. Second while the mean BMI, WC and WHR measurements of our men subjects were similar with the results of TEKHARF, the general obesity ratio (42%) and the mean anthropometric variables were lower in our women subjects.[16] The mean BMI was 2 kg/m^2, WC was 1.5 cm, and WHR was 0.4 lower in our female subjects.

As a single variable of peripheral fat accumulation TSF had no effect on blood pressure in either genders for our subjects. In the Framingham study both subscapular and TSF were studied and these two variables are found to be correlated to BMI.[27] In the first Health and Nutrition Survey (1971–1974) subscapular skin fold was found to be a better predictor of blood pressure, sharing all of the association of TSF with blood pressure and having significant predictive power not shared by TSF.[28] In Nortwick Park Heart Study TSF was found to be correlated with blood pressure and more strongly associated with the blood pressure than forearm skin fold. But an independent association is not suggested in multiple regression models.[29] When compared to other anthropometric variables such as BMI or WC, TSF has some disadvantages. First of all it may be rather subjective and the medical stuff must have standardized training. Furthermore, there is no common agreement about the definite cut-off point for skin folds.

Implications for practice

There is a growing common opinion that WC should be considered as a 'vital sign' and recorded in the same manner as weight and height in the medical chart of every patient. Some investigators claim that WC could replace both BMI and WHR as a simple indicator of need for weight management as a health promotion activity.[19,21] Measurement of WC alone as a proxy of abdominal fat mass has been suggested as a simple clinical alternative to BMI for detecting adults with possible health risks due to obesity.[24,25] Our results support this suggestion for screening for android obesity and following this measurement in patients with elevated blood pressure. This may reduce the chance of missing android obesity in patients that may have moderate or high risk of CVD that will occur if only BMI is used.

Study limitations

Our study may have some limitations in data gathering like all cross-sectional studies. Although the researchers had been trained by a standardized protocol of BP measurements, all of the estimations are made in one occasion. Measurements at single visit may lead to incorrect values for the BP. Also while our results represent the population of Edirne without the subjects who were using antihypertensive medication it is possible that among our study group there were hypertensive subjects who were not medicated but might using other life style factors to decrease BP (like daily salt intake etc.). They were included in the study because of the subjectivity to define some of the life-style factors. These factors might have effect on our results. But as far as we know this is the only regional study to define the relation of the BP with antropometric parameters in Turkey.

Implication for research

Cross national, regional and clinical studies in primary care including patients who were using anti hypertensive medication are needed to evaluate the effects of anthropometric variables on BP because of the heterogeneity of the patients.

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