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Relative importance of body mass index and waist circumference for hypertension in adults

ABSTRACT

OBJECTIVE: To assess the relative importance of Body Mass Index (BMI) and waist circumference for the determination of hypertension in adults.

METHODS: Cross sectional analysis of a sample of employees (N=1,584), aged 18 to 64 years, from a private general hospital in the city of São Paulo, Brazil. Data collection included the application of a structured questionnaire and blood pressure, weight, high, and waist circumference measurements. Hypertension was defined as blood pressure levels ≥ 140/90 mmHg or reported use of anti-hypertensive medication. The relative importance of BMI and waist circumference was evaluated by calculating the attributable fraction of hypertension corresponding to each anthropometric indicator, employing both the usual cut-off points as well as cut-off points based on the observed distribution of the indicator in the population. In addition, an indicator combining simultaneously BMI and abdominal circumference values was also developed.

RESULTS: Prevalence of hypertension was 18.9% (26.9% in men and 12.5% in women). In men, the fraction of hypertension attributable to BMI exceeded the fraction attributable to waist circumference based on the usual cut-off points for the indicators (56% vs. 48%, respectively) and also considering the quartiles of the observed distribution for these indicators (73% vs. 69%, respectively). In women, the fraction of hypertension attributable to waist circumference was slightly higher than the fraction attributable to BMI based on the usual cut off points for both indicators (44% vs. 41%), but the reverse was true when quartiles of the observed distribution were used (41% vs. 57%, respectively). In women only, the fraction of hypertension attributable to the indicator combining BMI and waist circumference (64%) was higher that observed using each indicator alone.

CONCLUSIONS: Both BMI and abdominal circumference were positively and independently associated with the occurrence of arterial hypertension, the influence of BMI being higher among men.

KEY WORDS: Hypertension. Body mass index. Abdominal circumference. Obesity. Attributable fraction.

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INTRODUCTION

Several studies provide evidence for an association between arterial hypertension and anthropometric indicators that reflect excess adipose tissue. Major indicators in this context are abdominal circumference[7,22] – which would provide a measure especially of visceral fat – and the body mass index (BMI), obtained by dividing weight in kilograms by the square of height in meters, which would reflect the proportion of adipose tissue in the total body mass, regardless of localization.[2,4,11]

Studies attempting to compare the associations with BMI and abdominal circumference have arrived at conflicting conclusions. While certain studies show better associations for BMI, others find that abdominal circumference is the better indicator, with results that often vary according to sex.[1,6,8,20,21,25]

The objective of the present study was to evaluate, in a population of Brazilian adults, the relative importance of BMI and abdominal circumference in the occurrence of arterial hypertension.

METHODS

The study population comprised a sample from the operational, administrative, and health care staff of a private general hospital in the municipality of São Paulo, Brazil. In November 2001, a campaign was conducted to diagnose the level of cardiovascular risk among the hospital staff. At the time, the total number of staff members was 3,623 (1,403 men and 2,220 women). All workers were invited to participate by means of posted signs and through the hospital's internal computer network. Of these, 1,584 workers agreed to take part in the campaign, of which 707 were men and 877 were women. Our study population was composed of these subjects. Studied and non-studied staff members did not differ significantly in terms of sex, age, and schooling.

Data collection was carried out during the five days of the campaign – which lasted from Monday to Friday, from 7 a.m. to 9 p.m. – by teams composed of nursing students, who were trained and supervised. Information was obtained through a structured questionnaire, which included data on age, sex, skin color, schooling, physical activity, drinking, work shift, and smoking. Standardized techniques were used to obtain anthropometric[10] and blood pressure[19] measurements. Weight was measured with subjects wearing light clothing and no shoes, using previously calibrated microelectronic scales (Tanita) with 100 g precision. Height was measured using a stadiometer (Seca) mounted on the wall, with 0.1 cm precision. Arterial pressure was measured once with the subject standing, after a resting period of approximately five minutes, using a previously calibrated, certified, BP 3BTO-A instrument (Microlife) with 1 mmHg resolution.[13] Abdominal circumference was measured at the midpoint between the last rib and the iliac crest, using an inextensible measuring tape.

We considered as hypertensive all subjects with systolic arterial pressure ≥140 mmHg and/or systolic arterial pressure ≥90 mmHg, as well as all those under antihypertensive medication.

The classification of subjects according to anthropometric indicators initially considered the standard cutoff points for BMI and abdominal circumference, which define values considered as normal, moderately high, and high. In the case of BMI, regardless of sex, these ranges correspond to <25, 25-29.9, and ≥30 kg/m², respectively.[24] In the case of abdominal circumference, these same classes correspond to, respectively, <94, 94-101.9, and ≥102 cm for men, and <80, 80-87.9, and ≥88 cm for women.[12] As a next step, we alternatively classified BMI and abdominal circumference based on quartiles of distribution in the studied population, separated by sex.

In order to produce a classification that took into account both indicators simultaneously, BMI and abdominal circumference values were transformed into z-scores in order to create a new indicator. This indicator was defined as the sum of the z-scores for each indicator, and was classified into quartiles, as previously done for BMI and abdominal circumference.

The study of the importance of BMI, abdominal circumference, and the combined indicator in determining arterial hypertension included initially an evaluation of bivariate associations between anthropometric indicator classes and presence of arterial hypertension. For this we used test based on the chi-squared distribution. We then evaluated the association of potential confounders in the association between anthropometric indicators and arterial hypertension. These included age, schooling, skin color, frequency of physical exercise, smoking, frequency of consumption of alcoholic beverages, and work shift. All potential confounders whose association with arterial hypertension showed p-values below 0.2 in the chi-squared test were introduced, one-by-one, into logistic regression models for arterial hypertension as a function of, alternatively, BMI, abdominal circumference, and the combined indicator. Adjusted odds ratios for arterial hypertension were given by final regression models that included all confounders determining variations of at least 10% in the odds ratios associated with the anthropometric indicators. We also checked for the potential occurrence of significant interactions between each anthropometric indicator and the variables included in the final regression models.

The importance of each anthropometric indicator in the determination of arterial hypertension was quantified based on the calculation of the corresponding population attributable fraction. The attributable fraction was calculated based on the formula [H – 1/H * 100, with H = f1 x 1 + f2 x OR2 + f3 x OR3 + f4 x OR4], where f1 is the frequency of subjects in the baseline category of the anthropometric indicator ("unexposed to risk"), f2, f3, and f4, are the frequencies in the risk categories of the indicator, and OR2, OR3, and OR4 are the adjusted, odds ratios for arterial hypertension in each risk category for that indicator.[9]

Given the systematic differences found between sexes regarding the association between anthropometric indicators and arterial hypertension, all analyses were performed separately for both sexes. All analyses were carried out using SPSS version 10.0 software.

All staff members included in the study signed a term of free and informed consent. The study protocol was approved by the Departamento de Medicina do Trabalho and the Instituto de Ensino e Pesquisa do Hospital Israelita Albert Einstein, as well as by the Research Ethics Committee of the Faculdade de Saúde Pública da USP.

RESULTS

Prevalence of arterial hypertension was 26.9% among males, 12.5% among females, and 18.9% in the general population. Among men, there was a significant increase in prevalence associated with age and with working the night shift. Among women, prevalence of hypertension varied significantly with age (direct relationship), schooling (inverse relationship), and ethnicity (higher prevalence among nonwhites) (Table 1).

A little over one-half of men and a little over one-third of women had BMIs above the upper limit of the normal range (≥25 kg/m^2). Abdominal circumference values above the upper limit (94 cm for men and 80cm for

Table 1. Prevalence (%) of arterial hypertension according to variables among men and women. São Paulo, Brazil, 2001.

Variable	N	Men	p	Women	p
Age (years)			< 0.01		< 0.01
18 to 24	31	20.5		3.3	
25 to 29	49	23.1		6.1	
30 to 34	46	21.6		7.9	
35 to 39	58	31.0		13.9	
40 to 44	39	38.6		11.9	
45 to 49	36	40.9		23.1	
50 to 64	41	41.7		55.4	
Ethnicity			0.13		0.02
White	235	25.6		11.5	
Nonwhite	65	32.3		19.3	
Schooling			0.9		< 0.01
Primary	72	28.0		27.3	
Secondary	157	27.0		13.8	
Higher	71	25.8		5.9	
Work shift			< 0.01		0.09
Day	246	24.8		11.9	
Night	54	40.9		18.6	
Physical activity (days/week)			0.97		0.87
0	181	27.0		12.3	
1	41	26.9		14.8	
2 to 3	51	25.7		11.7	
≥ 4	27	28.8		15.1	
Alcoholic beverage consumption (times/week)			0.07		0.6
0	234	25.0		12.8	
≥ 1	66	32.2		9.7	
Smoking (cigarettes/day)			0.96		0.34
0	256	26.8		13.2	
< 10	25	25.7		8.1	
≥ 10	19	29.6		9.4	
Arterial hypertension (%)	300	26.9		12.5	

p: p-value for linear trend

Table 2. Distribution (%) of body mass index and abdominal circumference among men and women. Sao Paulo, Brazil, 2001.

Variable	Men		Women	
	%	N=707	%	N=877
BMI (kg/m²)				
< 25	47.5	336	64.7	567*
25-29	41.2	291	25.9	227
≥ 30	11.3	80	9.4	83
Abdominal circumference (cm):				
< 94	62.5	442*	-	-
94 - 101	22.9	162	-	-
≥ 102	14.6	103	-	-
Abdominal circumference (cm):				
< 80	-	-	44.6	391*
80-87	-	-	31.8	279
≥ 88	-	-	23.6	207

*p<0.05: Chi-square test for the comparison of distribution between both sexes.
BMI: Body Mass Index

Table 3. Prevalence (%) of arterial hypertension according to anthropometric indices among men and women. São Paulo, Brazil, 2001.

Variable	Men	Women
BMI (kg/m²)		
< 25	15.8*	6.7*
22-29	30.9	15.9
≥ 30	58.8	43.4
BMI quartiles		
1	10.2*	4.1*
2	21.5	7.8
3	27.1	10.5
4	48.6	27.7
Abdominal circumference (cm)		
< 94	17.9*	-
94-101	32.7	-
≥ 102	56.3	-
Abdominal circumference (cm)		
< 80	-	5.4*
80-87	-	8.6
≥ 88	-	31.4
Abdominal circumference quartiles		
1	11.2*	5.0*
2	20.9	5.3
3	26.2	10.0
4	48.9	28.8
Quartiles for the sum of z-scores of BMI and abdominal circumference		
1	9.6*	4.6*
2	12.6	7.1
3	26.9	13.3
4	41.3	38.0

p<0,01 for linear trend

women) were found in a little over one-third of men and a little over one-half of women (Table 2).

For both sexes, there was a uniform and significant increase ($p<0.01$ for linear trend) in prevalence of arterial hypertension with increases in BMI and abdominal circumference. This occurred both when we used the standard cutoffs for BMI and/or abdominal circumference and when we used a classification based on quartiles for the analysis (Table 3).

Table 4, restricted to males, shows the adjusted odds ratios for hypertension and the corresponding fractions of disease attributable to the anthropometric indicators. Age and schooling emerged as adjustment variables in all final regression models. There were no significant interactions between the anthropometric indicators and these variables. The fraction of arterial hypertension attributable to BMI exceeded that attributable to abdominal circumference both when the standard cutoff points for the indicator (56% vs. 48%, respectively) and the quartiles of the observed distribution (73% vs. 69%, respectively) were employed. Classification according to quartiles showed an increase in occurrence of arterial hypertension for intervals of BMI (between 22.9 and 25.2 kg/m^2) and abdominal circumference (between 84 and 91 cm) considered as normal based on the traditional cutoff points for these indicators. The attributable fraction for the indicator combining BMI and abdominal circumference among men was 67%, and therefore lower than the attributable fraction for each indicator alone.

Table 5 presents the adjusted odds ratios for hypertension and the corresponding fractions of disease attributable to the anthropometric indicators among

Table 4. Adjusted odds ratios for arterial hypertension and the corresponding population attributable fraction associated to different anthropometric indicators among men. São Paulo, Brazil, 2001.

Index	% hypertensive	ORadj*	95% CI	PAF (%)
BMI (kg/m^2)				
< 25	15.8	1	-	-
25 - 29	30.9	2.4	1.6;3.6	25
≥ 30	58.8	7.3	4.2;12.7	31
≥ 25	-	-	-	56
Abdominal circumference (cm)				
< 94	17.9	1	-	-
94 - 101	32.7	2.1	1.4;3.3	13
≥ 102	56.3	5.6	3.4;9.0	35
≥ 94	-	-	-	48
BMI quartiles (kg/m^2)				
1 (< 22,9)	10.2	1	-	-
2 (22,9 - 25,2)	21.5	2.4	1.3;4.4	9
3 (25,3 - 27,7)	27.1	3.2	1.7;5.8	15
4 (≥ 27,8)	48.6	8.4	4.6;15.2	49
2+3+4	-	-	-	73
Abdominal circumference quartiles (cm)				
1 (< 84)	11.2	1	-	-
2 (84 - 90)	20.9	2.1	1.1;3.7	8
3 (91 - 97)	26.2	2.7	1.4;4.9	13
4 (≥ 98)	48.9	7.3	4.0;13.2	48
2+3+4	-	-	-	69
Quartiles for the sum of z-scores of BMI and abdominal circumference				
1	.6	1	-	-
2	12.6	1.4	0.6;3.2	3
3	26.9	3.4	1.6;7.4	19
4	41.3	6.6	3.0;14.1	45
2+3+4	-	-	-	67

* Odds ratio adjusted for age and schooling.
PAF: population attributable fraction

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BMI (kg/m²)				
< 25	15.8	1	-	-
25 - 29	30.9	2.4	1.6;3.6	25
≥ 30	58.8	7.3	4.2;12.7	31
≥ 25	-	-	-	56
Abdominal circumference (cm)				
< 94	17.9	1	-	-
94 - 101	32.7	2.1	1.4;3.3	13
≥ 102	56.3	5.6	3.4;9.0	35
≥ 94	-	-	-	48
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3 (25,3 - 27,7)	27.1	3.2	1.7;5.8	15
4 (≥ 27,8)	48.6	8.4	4.6;15.2	49
2+3+4	-	-	-	73
Abdominal circumference quartiles (cm)				
1 (< 84)	11.2	1	-	-
2 (84 - 90)	20.9	2.1	1.1;3.7	8
3 (91 - 97)	26.2	2.7	1.4;4.9	13
4 (≥ 98)	48.9	7.3	4.0;13.2	48
2+3+4	-	-	-	69
Quartiles for the sum of z-scores of BMI and abdominal circumference				
1	.6	1	-	-
2	12.6	1.4	0.6;3.2	3
3	26.9	3.4	1.6;7.4	19
4	41.3	6.6	3.0;14.1	45
2+3+4	-	-	-	67

* Odds ratio adjusted for age and schooling.
PAF: population attributable fraction

females. Again, age and schooling were kept in the final regression models as confounding variables, and again there was no significant interaction between anthropometric indicators and these variables. The fraction of female arterial hypertension attributable to abdominal circumference was slightly higher than that attributable to BMI when standard cutoff points were used for both indicators (44% vs. 41%, respectively). However, when quartiles were employed, the explanatory power of BMI exceeded that of abdominal circumference (attributable fractions of 57% and 41%, respectively). Again, classification according to quartiles showed increased occurrence of arterial hypertension in intervals of BMI (between 21.7 and 23.6 kg/m²) considered as normal according to the standard classification. However, the same was not true for abdominal circumference. The explanatory power of the combined indicator for women (attributable fraction of 64%) was higher than that of BMI or abdominal circumference alone.

DISCUSSION

Our results indicate that both BMI and abdominal circumference have an important association with arterial hypertension in both sexes, even after control for relevant confounders. Depending on the classification employed, the fraction of arterial hypertension attributable to these indicators ranged from 48% to 73% among men and 41% to 64% among women. Among men, explanatory power for the occurrence of arterial hypertension, as measured by the population attributable fraction, was greater for BMI than for abdominal circumference, regardless of the classification used. Among women, the greater power of BMI over abdominal circumference was only apparent when the classification based on quartiles of the observed distribution in that population was used. The explanatory power of the indicator combining BMI and abdominal circumference was greater than that of each indicator alone only among women. The classification of indicators based on the distribution observed in the population rather than on the usual cutoff points increased the explanatory power of BMI among women and of both BMI and abdominal circumference among men. These results indicate the occurrence of arterial hypertension at levels of BMI and abdominal circumference lower than those established by traditional classifications.

Certain limitations should be taken into consideration when interpreting the results of the present study. The first concerns the particularities of the study sample – the staff of a private hospital in the city of São Paulo – which limits the extrapolation of results to other settings. The second limitation is that diagnosis of arterial hypertension was based on a single measurement, when ideally it would be based on two measurements obtained at different times.[5] Finally, the cross-sectional design of the study does not ensure the temporal precedence of anthropometric measures over the occurrence of arterial hypertension.

On the other hand, strengths of the present study include a wide demographic and socioeconomic diversity within the sample, the obtainment of anthropometric and blood pressure measures by direct measurement rather than by self-report, control for relevant confounders in the estimates of association between anthropometric indicators and hypertension, and the analytic procedures employed, which ensure comparability of evaluation and in terms of explanatory power of anthropometric indexes in the determination of arterial hypertension.

Studies comparing the relative importance of BMI and abdominal circumference among adults frequently employ regression analyses or analyses based on ROC curves. Thus, a comparison of these results with those of the present study are not direct or immediate. While certain studies show stronger associations for BMI, others find that abdominal circumference is the better indicator, with results that often vary according to sex.[1,6,8,20,21,25] However, most of these studies employ a priori classifications for these two indices, which do not necessarily maximize the explanatory power of the indicators in an equal manner. In some of these studies, it was shown that the simultaneous consideration of both BMI and abdominal circumference could increase explanatory power above that of individual indices alone, both among women only,[1,8] as found in the present study, or for both sexes.[23,26]

The choice of using the attributable fraction as a means to measure the explanatory power of each index was based mainly on the ease of interpretation provided by this method. The attributable fraction indicates the proportion of occurrence of the disease that would be eliminated if individuals remained unexposed to the risk condition under study ("high values" of BMI, abdominal circumference, or the combined index). In addition, sensitivity and specificity calculations and ROC curves require dichotomous variables, which is not the case for BMI and abdominal circumference. Finally, the attributable fraction allows for confounder control in the association between studied variable and outcome.

We found only six studies in the literature using the population attributable fraction to investigate the importance of abdominal circumference and/or BMI in determining arterial hypertension. Five of these evaluate only abdominal circumference, identifying attributable fractions for arterial hypertension ranging from 5.8% to 30% among men and 11.1% to 66.5% among women.[14-18] One of these studies calculated the attributable fraction of hypertension associated with circumference with and without controlling for BMI, and identified a substantial reduction in the explanatory power of circumference after controlling for BMI in both sexes.[16] The only study comparing the attributable fractions of arterial hypertension associated to BMI and abdominal circumference found similar explanatory power for both indicators (population attributable fraction of about 40% for both sexes).[3] There is no record in the literature of studies calculating the attributable fraction of arterial hypertension in relation to an indicator combining BMI and abdominal circumference.

In conclusion, the results of the present study confirm data from the literature that indicate a high explanatory power for both BMI and abdominal circumference in determining arterial hypertension. This suggests that increase in fat deposits may increase risk of disease, be it in the abdominal region, or in other parts of the body. Our results indicate that not only fat deposits in the abdominal region should be considered as hazardous to health, since the population attributable fraction for hypertension associated with BMI was greater than that found for abdominal circumference, especially among men. Furthermore, among women, the combination of BMI and abdominal circumference increased the explanatory power of each index alone. We also draw attention to the observation that the classification of BMI and abdominal circumference based on the distribution of these indexes in the studied population showed that values usually regarded as normal are already associated with increased occurrence of arterial hypertension, which indicates a need for revision of traditional classifications.

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