Original Article

Upper Arm Circumference Is an Independent Predictor of Left Ventricular Concentric Hypertrophy in Hypertensive Women

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Upper arm circumference (UAC) measurement is necessary for the proper sizing of cuffs and is recommended for accurate blood pressure (BP) assessment. The aim of this report is to identify and quantify the relationships between UAC and the usual anthropometric measurements of body fat distribution and cardiac structure in hypertensive subjects. We evaluated 339 patients (202 women and 137 men) by medical history, physical examination, anthropometry, metabolic and inflammatory parameters, and echocardiography. Partial correlation analyses adjusted for age and body mass index revealed that anthropometric variables were significantly associated with echocardiographic parameters exclusively in women. In this regard, UAC correlated with interventricular septum thickness, posterior wall thickness, and relative wall thickness ≥ 0.45 , while waist circumference was related to left cardiac chamber diameter. Multivariate analyses including age, body mass index, systolic BP, homeostasis model assessment index, and use of antihypertensive medications demonstrated that UAC was an independent predictor of left ventricular wall thickness and concentric hypertrophy in women. Further linear regression analyses revealed that waist circumference was an independent predictor of left ventricular end-diastolic and left atrial diameters in this gender. Overall, these findings suggest that UAC determination might serve not only as a routine approach preceding BP evaluation but also as a simple and feasible predictor of adverse LV remodeling in hypertensive women. (*Hypertens Res* 2008; 31: 1177–1183)

Key Words: hypertension, upper arm circumference, waist, left ventricular mass, concentric hypertrophy

Introduction

Hemodynamic stress imposed by arterial hypertension stimulates changes in the left ventricular (LV) structure, which includes myocardial hypertrophy and an increase in relative wall thickness (1). Although these adaptations are often considered to normalize hemodynamic overload, with time they

mediate the transition from arterial hypertension to major cardiovascular adverse events (2). In this regard, elevated risk associated with LV hypertrophy and increased relative wall thickness in part reflects the impact of adverse arterial conditions on the left ventricle, but is also related to direct negative effects of myocardial remodeling on ventricular function (1,3).

Obesity accentuates the incidence and magnitude of LV damage in hypertensive subjects by stimulating increments in

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both chamber size and wall thickness (4). It has been assumed that obesity-related LV chamber enlargement is attributable to volume overload derived from an accumulation of excess body fat (5). Recent studies have, however, shown that relative wall thickness also tends to increase along with body fat accumulation irrespective of blood pressure (BP) levels (4, 6), indicating that stimuli other than hemodynamic factors are also likely involved in the development of LV remodeling in obese people (6).

Visceral fat accumulation is clearly related to increased cardiovascular risk (7). In this context, waist circumference (waist) and waist-to-hip ratio have been the foci of much recent public health attention as informative, simple, and convenient indicators of obesity and related health risks (8). Otherwise, studies evaluating the impact of peripheral adiposity on cardiovascular risk have yielded conflicting results. Previous reports suggested that excessive peripheral fat mass might exert insulin-sensitizing and anti-atherogenic effects (9, 10). In contrast to this supposition, recent data from the Framingham Heart Study demonstrated that peripheral adiposity is associated with increased cardiovascular risk, albeit in a minor proportion when compared to central adiposity (11).

Upper arm circumference (UAC) measurement is necessary for the proper sizing of cuffs (12) and is widely recommended for accurate BP assessment (12, 13). Moreover, this anthropometric variable exhibits a strong correlation with limb fat mass, particularly in women, which confers upon UAC a consistent ability to evaluate peripheral adiposity (14, 15). Whether or not UAC predicts hypertensive cardiac damage remains poorly understood. Thus, the aim of this report is to identify and quantify relationships between UAC and the usual anthropometric measurements of body fat distribution as well as echocardiographic markers of cardiac remodeling in hypertensive subjects.

Methods

The study was carried out in 339 hypertensive subjects, comprising 202 women and 137 men, who were followed up at the Hypertension Unit of the hospital of the State University of Campinas. Hypertension was defined as systolic BP higher than 140 mmHg or diastolic BP higher than 90 mmHg or as current use of antihypertensive medication. Diabetes mellitus was diagnosed if fasting blood glucose was ≥ 126 mg/dL or when participants were taking hypoglycaemic medications, while metabolic syndrome was defined in accordance with NCEP Panel III criteria (16). Women with reported amenorrhea for more than 12 months, except for pregnancy, were identified as postmenopausal. The main exclusion criteria were age under 18 years, significant cardiac valve disease, hypertrophic cardiomyopathy, previous myocardial infarction, and neoplastic disease. The study was approved by the Ethics Committee of the State University of Campinas, and written consent was obtained from all participants.

Anthropometric measurements included body mass index

(BMI), waist, hip, waist-to-hip ratio, UAC, and waist-to-UAC ratio. BMI was calculated as body weight divided by height squared (kg/m^2). Waist was measured at the midpoint between the lowest rib and the iliac crest and hip at the level of the greater trochanters. The waist-to-hip ratio was calculated by dividing the waist measurement by the hip measurement. UAC was considered as the measurement at the midpoint between the acromion and olecranon from the arm with higher circumference, and the waist-to-UAC ratio was calculated as waist divided by UAC.

Considering that physical activity might influence UAC free-fat mass content, all patients were questioned about their daily exercise. None of the patients were performing physical labor on the job, while regular recreational exercise using the upper limbs was performed by only 1 man (body-building) and 3 women (hydrogymnastics or body-building), indicating that physical activity was not a potential confounder in our analysis.

Blood pressure was measured using a validated digital oscillometric device (HEM-705CP; Omron Healthcare, Kyoto, Japan) with appropriate cuff sizes. Two readings were averaged and, if they differed by more than 5 mmHg, one additional measurement was performed and the average of the three measurements was taken.

After the patients had fasted for 12 h, blood samples were obtained in the morning from an antecubital vein for analysis of total cholesterol, glucose, insulin, and C-reactive protein levels. The homeostasis model assessment index (HOMA) was calculated as: $\text{Glucose (mg/dL)} \times \text{Insulin } (\mu\text{U/mL}) / 405$ (10).

Echocardiographic studies were performed on each subject at rest in the left lateral decubitus position using a PowerVision 6000 ultrasound system (Toshiba, Tokyo, Japan) with a 2.5 MHz transducer as previously described (17). Two-dimensional guided M-mode was used to measure LV end-diastolic dimension (LVED), interventricular septum thickness, posterior wall thickness, and left atrial size. Relative wall thickness was computed as twice the posterior wall thickness divided by LVED. LV hypertrophy was defined with the use of a cutoff point LV mass/body surface area of $> 125 \text{ g/m}^2$ for men and 110 g/m^2 for women (18) or LV mass/height^{2.7} $> 51 \text{ g/m}^{2.7}$ for both genders (19). Normal LV mass index or LV hypertrophy coupled with relative wall thickness ≥ 0.45 (1, 20) was defined as concentric remodeling or concentric hypertrophy, respectively. Conversely, normal LV mass index or LV hypertrophy in the presence of relative wall thickness < 0.45 was considered normal ventricular structure or eccentric hypertrophy, respectively. All recordings were made by the same physician, who was unaware of other data relating to the subjects. The reproducibility of both acquiring and measuring LV mass and left atrial size was determined in recordings obtained from 10 subjects. Intraobserver LV mass and left atrial size variability was $< 7\%$, whereas interobserver variability of these parameters was $< 10\%$.

Descriptive statistical results are given as means $\pm$ SEM.

Table 1. Clinical and Demographic Features of Hypertensive Patients

Variables	Female (n=202)	Male (n=137)
Age, years	57.9±0.8	58.4±1.1
Height, m	1.54±0.01	1.67±0.01*
Weight, kg	76.2±1.2	84.1±1.4*
Body mass index, kg/m ²	32.1±0.5	30.1±0.5*
Waist, cm	101.8±1.0	104.0±1.0
Hip, cm	108.9±0.9	105.7±0.7*
Waist-to-hip ratio	0.94±0.01	0.98±0.01*
UAC, cm	33.8±0.3	32.5±0.3*
Waist-to-UAC ratio	3.03±0.02	3.20±0.02*
Systolic blood pressure, mmHg	153.8±2.1	150.0±2.4
Diastolic blood pressure, mmHg	87.6±1.1	85.6±1.3
Diabetes mellitus, n (%)	50 (25)	35 (26)
Metabolic syndrome, n (%)	130 (64)	87 (63)
Postmenopause, n (%)	126 (62)	—
Total cholesterol, mg/dL	195.7±3.2	177.2±3.0*
Fasting blood glucose, mg/dL	114.0±3.3	111.7±3.2
Insulin, µU/mL	14.8±0.7	13.4±0.8
HOMA	4.27±0.25	3.81±0.29
C-Reactive protein, mg/dL	0.72±0.10	0.66±0.12

UAC, upper arm circumference; HOMA, homeostasis model assessment index. * $p < 0.05$.

The χ^2 test and unpaired t -test were used to compare categorical and continuous variables, respectively. Univariate relations between BMI and echocardiographic parameters were assessed by Pearson correlation coefficients. Associations between other studied variables and echocardiographic parameters were assessed by partial correlation coefficient covariate of age and BMI. Variables that showed significant relationships with left cardiac chambers or could potentially interact with anthropometric measurements were considered independent variables in multiple linear regression analyses. Differences in UAC average measurements among the four LV geometric patterns were evaluated by one-way ANOVA followed by the Tukey test for pairwise comparisons. A p -value of less than 0.05 was considered significant.

Results

Patient Characteristics

The clinical and demographic features of the enrolled patients are presented in Table 1, while echocardiographic characteristics and current antihypertensive medications are shown in Table 2. There were significant differences between women and men for height, weight, BMI, hip, UAC, waist-to-hip ratio, waist-to-UAC ratio, and total cholesterol levels (Table 1). In addition, LVED, left atrial size, interventricular septum thickness, posterior wall thickness, and LV mass/body sur-

Table 2. Echocardiographic Features and Antihypertensive Medications of Hypertensive Patients

Variables	Female (n=202)	Male (n=137)
LVED, mm	49.0±0.3	53.1±0.6*
Left atrial size, mm	38.5±0.3	42.0±.6*
Posterior wall thickness, mm	11.0±0.1	11.7±0.1*
Interventricular septum, mm	11.2±0.1	12.0±0.1*
Relative wall thickness	0.45±0.01	0.44±0.01
LV mass/BSA, g/m ²	147.9±2.8	169.2±4.3*
LV mass/height ^{2.7} , g/m ^{2.7}	80.5±1.7	81.9±2.2
LV hypertrophy (g/m ²), n (%)	167 (83)	111 (81)
LV hypertrophy (g/m ^{2.7}), n (%)	184 (91)	125 (91)
Use of antihypertensives, n (%)	198 (98)	134 (98)
Diuretics, n (%)	163 (81)	112 (82)
β -Blockers, n (%)	189 (51)	82 (60)
Calcium channel blockers, n (%)	89 (44)	65 (48)
ACEI or ARB, n (%)	161 (80)	116 (85)

LVED, left ventricular end-diastolic dimension; LV, left ventricular; BSA, body surface area; ACEI or ARB, angiotensin converting enzyme inhibitors or angiotensin receptor blockers use. * $p < 0.05$.

face area were greater in men (Table 2).

Correlations between Anthropometric Measures and Echocardiographic Parameters

Univariate regression analysis demonstrated that BMI was related to echocardiographic parameters in both genders. BMI significantly correlated with LVED ($r=0.24$ for women and men), interventricular septum thickness ($r=0.47$ for women and $r=0.23$ for men), posterior wall thickness ($r=0.36$ for women and $r=0.21$ for men), relative wall thickness ≥ 0.45 ($r=0.25$ for women), LV mass/height^{2.7} ($r=0.40$ for women and $r=0.30$ for men), LV mass/body surface area ($r=0.15$ for women), and left atrial size ($r=0.39$ for women and $r=0.35$ for men).

The relationships between anthropometric measures of body fat distribution and echocardiographic parameters were then analyzed by partial correlation coefficients, covariate of age, and BMI. In hypertensive women (Table 3), UAC was associated with interventricular septum thickness, posterior wall thickness, and relative wall thickness ≥ 0.45 , while waist was related to LVED and left atrial size. No anthropometric variable was significantly associated with LV mass indexes in hypertensive women. Partial correlation analysis also demonstrated associations between non-anthropometric variables and echocardiographic parameters. Systolic BP, use of CCBs, and use of angiotensin-converting-enzyme inhibitors/angiotensin receptor blockers were directly related to LV wall thickness and relative wall thickness ≥ 0.45 , while diastolic BP and the number of antihypertensives per patient were pos-

Table 3. Partial Correlations between Studied Variables and Echocardiographic Parameters in Hypertensive Women Adjusted for Age and Body Mass Index

Variables	LVED	PWT	IVS	RWT ≥ 0.45	LVM/BSA	LVM/height ^{2.7}	LA
Waist	0.18*	0.12	0.08	0.01	0.11	0.08	0.21 [†]
Hip	0.12	-0.02	-0.06	-0.08	-0.04	-0.08	0.04
Waist-to-hip	0.07	0.11	0.11	0.06	0.12	0.13	0.13
UAC	0.07	0.21 [†]	0.19 [‡]	0.18*	0.12	0.10	0.13
Waist-to-UAC	0.06	-0.05	-0.06	-0.13	0.01	-0.03	0.04
Systolic BP	-0.16*	0.29 [‡]	0.30 [‡]	0.19 [‡]	0.12	0.11	-0.03
Diastolic BP	-0.05	0.28 [‡]	0.26 [‡]	0.11	0.17*	0.15*	-0.04
β -Blockers	0.22 [†]	0.02	0.05	-0.13	0.07	0.07	0.01
CCB	0.06	0.15*	0.19 [‡]	0.15*	0.11	0.14*	0.07
ACEI or ARB	0.05	0.15*	0.16*	0.14*	0.13	0.17*	0.05
Number of AH	0.12	0.17*	0.22 [†]	0.08	0.19 [‡]	0.22 [†]	0.10

LVED, left ventricular end-diastolic dimension; PWT, posterior wall thickness; IVS, interventricular septum; RWT, relative wall thickness; LVM, left ventricular mass; BSA, body surface area; LA, left atrial dimension; UAC, upper-arm circumference; BP, blood pressure; CCB, calcium channel blockers; ACEI or ARB, angiotensin converting enzyme inhibitors or angiotensin receptor blockers use; AH, antihypertensives. * $p < 0.05$; [†] $p < 0.01$; [‡] $p < 0.001$.

Table 4. Upper Arm Circumference Values According to Left Ventricular Geometric Patterns in Hypertensive Women

LV geometric pattern	N	UAC, cm
Normal	26	32.8 $\pm$ 0.7
Concentric remodeling	9	31.9 $\pm$ 0.6
Eccentric hypertrophy	80	32.5 $\pm$ 0.5
Concentric hypertrophy	87	35.6 $\pm$ 0.5* [‡]

LV, left ventricular; UAC, upper arm circumference. LV hypertrophy: LV mass/body surface area > 110 g/m². * $p < 0.05$ in comparison to normal LV structure and concentric remodeling; [†] $p < 0.001$ in comparison to eccentric hypertrophy.

itively associated solely with LV wall thickness. Otherwise, LVED was directly related to use of CCBs and negatively associated with systolic BP (Table 3). Finally, no significant correlation was found between use of diuretics, diabetes mellitus, HOMA, metabolic syndrome, or C-reactive protein and any echocardiographic parameter.

In hypertensive men, no significant relationships were found between anthropometric measures and echocardiographic parameters analyzed by partial correlation coefficients, covariate of age, and BMI (see Online Table 1).

UAC and LV Geometric Patterns in Hypertensive Women

Given the significant association between UAC and relative wall thickness ≥ 0.45 but not with LV mass index, we investigated whether or not there were differences on UAC values in hypertensive women according to the presence of concentric hypertrophy, eccentric hypertrophy, concentric remodeling,

or normal LV structure. As shown in Table 4, mean UAC was significantly higher in hypertensive patients with concentric hypertrophy than in those with other LV geometric patterns.

Multivariate Analysis in Hypertensive Women

Considering that the relationships between anthropometric measurements and cardiac structure found in hypertensive women could be influenced by potential confounders, multiple regression analyses were performed. Included variables are shown in Table 5 and the corresponding legend. UAC was positively and independently related to interventricular septum, LV posterior wall thickness, and LV concentric hypertrophy. Conversely, waist was found to be an independent predictor of left atrial size, but showed no significant relationship with LVED in a model that included BMI, age, systolic BP, HOMA, and use of β -blockers. Nevertheless, withdrawal of BMI from this analysis did not change LVED variability prediction ($r^2 = 22\%$), but disclosed a significant association ($\beta = 0.257 \pm 0.079$, $p = 0.001$) between waist and this echocardiographic parameter, supporting the notion that central fat deposition was independently related to LV chamber diameter.

Discussion

The data obtained in the present study indicated that UAC is an independent predictor of concentric hypertrophy in hypertensive women, but not in hypertensive men. These results may add novel significance to UAC in the clinical evaluation of female hypertensive subjects. LV concentric hypertrophy is a marker of hypertensive cardiac damage and is associated with the worst cardiovascular outcomes among hypertension-related LV geometric patterns (1, 3, 21–23). Thus, the present

Table 5. Multiple Regression Analysis of the Association between Selected Independent Variables and Echocardiographic Parameters in Hypertensive Women

Variables	Posterior wall thickness ($r^2=0.31$)	Interventricular septum ($r^2=0.30$)	Concentric hypertrophy ($r^2=0.20$)	LVED ($r^2=0.22$)	Left atrial size ($r^2=0.17$)
UAC	0.349±0.127 [†]	0.354±0.129 [†]	0.307±0.130*	—	—
Waist	—	—	—	0.230±0.164	0.324±0.160*
Body mass index	0.128±0.128	0.075±0.131	0.021±0.132	0.027±0.161	0.105±0.172
Age	0.150±0.111	0.235±0.113*	−0.026±0.115	0.227±0.077 [†]	0.122±0.081
Systolic BP	0.201±0.075 [†]	0.240±0.076 [†]	0.157±0.077*	−0.279±0.078 [‡]	—
Postmenopause	0.034±0.110	−0.063±0.120	0.107±0.113	—	—
HOMA	0.056±0.076	−0.013±0.077	−0.040±0.078	0.042±0.138	−0.084±0.089
CCB	0.133±0.102	0.161±0.104	0.212±0.075 [†]	—	—
ACEI or ARB	0.161±0.085	0.163±0.086	0.225±0.075 [†]	—	—
β-Blocker	—	—	—	0.271±0.076 [‡]	—
Number of AH	−0.056±0.112	−0.047±0.113	—	—	—

Data are presented as β coefficient±SEM of β . LVED, left ventricular end-diastolic dimension; UAC, upper arm circumference; BP, blood pressure; HOMA, homeostasis model assessment index; CCB, calcium channel blockers; ACEI or ARB, angiotensin converting enzyme inhibitors or angiotensin receptor blockers use; AH, antihypertensives. Concentric hypertrophy: LV mass/body surface area > 110 g/m² and relative wall thickness ≥ 0.45. * $p < 0.05$; [†] $p < 0.01$; [‡] $p < 0.001$.

findings might point toward UAC as a potential tool with which to predict adverse LV remodeling in hypertensive women. Moreover, it should be highlighted that UAC utilization for this purpose would impose virtually no additional steps in the assessment of patients, since its evaluation has been routinely recommended in order to provide accurate BP measurement (12, 13).

The reasons whereby UAC did not associate with LV remodeling in males were not apparent in our study. However, potential explanations may reside in gender differences in UAC-related composition and BP variation. UAC has been reported to evaluate both peripheral fat mass and free-fat mass in men (15), whereas in women this anthropometric variable is considered a consistent predictor of peripheral fat mass but not of free-fat mass (14, 15). Since free-fat mass displays an inverse or neutral association with relative wall thickness (6, 24), it is possible that sex-derived variation in arm composition could explain the lack of a relationship between UAC and increased relative wall thickness in men. Moreover, the fact that higher UAC has been related to higher BP in females rather than males (25) could also help explain the association between this anthropometric measure and concentric hypertrophy in females.

Several lines of evidence demonstrate that the pattern of body fat distribution may influence LV geometry. For instance, central adiposity has been directly associated with LV chamber diameter in normotensive and hypertensive subjects (26–28). These observations are in accord with our findings of a positive association between LVED and waist in females, and suggest that increased circulating volume derived from central adiposity might stimulate LV remodeling. On the other hand, LV relative wall thickness also tends to increase along with body fat accumulation irrespective of

BP levels (4, 6). However, there has been conflicting evidence about a role for central adiposity in this process, since significant associations between central fat mass and relative wall thickness have been reported in small studies (29) but not in larger populations (27, 30). Alternatively, the relationship between UAC and concentric hypertrophy in hypertensive women shown here raises the hypothesis that peripheral adiposity might be a determinant of obesity-related LV relative wall thickness increase. Nevertheless, further studies are necessary to determine whether or not peripheral fat mass contributes to the development of LV remodeling in hypertensive subjects.

A potential limitation of this study is that the majority of hypertensive patients were taking medications. It is therefore possible that some findings were attributable to differential effects of various therapy regimens. However, we diminished this potential bias by considering, in multivariate models, the presence of antihypertensive treatment and the number of antihypertensive medications the subjects were taking at the time of the study. Moreover, univariate correlations between BMI and LV mass index observed in our sample were very similar to those reported in other hypertensive populations (31), strengthening the idea that use of medications did not significantly affect the relationships between anthropometric variables and echocardiographic parameters. On the other hand, it should be acknowledged that the use of multivariate analysis can minimize, but not rule out, the influences of the various confounding factors on the determination of echocardiographic parameters in our patients. This might constitute another potential limitation to this study.

In summary, the present report identified a positive relationship between UAC and concentric hypertrophy in hypertensive women but not in hypertensive men. These findings

point to UAC as a potential predictor of adverse LV remodeling in hypertensive women. Further studies are necessary to elucidate the mechanisms underlying these findings and to test the utility of UAC as a predictor of prognosis.

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