ORIGINAL ARTICLE

The association of metabolic syndrome with left ventricular mass and geometry in community-based hypertensive patients among Han Chinese

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Background: The association of metabolic syndrome (MS) with left ventricular (LV) hypertrophy is controversial. The objective of our study was to investigate the influence of MS on LV mass and geometry in community-based hypertensive patients among Han Chinese. **Materials and Methods:** This study included 1733 metabolic syndrome patients according to the International Diabetes Federation (IDF) definition and 2373 non-MS hypertension patients. LV hypertrophy was diagnosed by the criteria of LV mass ≥49.2 g/m$^{2.7}$ for men and 46.7 g/m$^{2.7}$ for women. LV geometric patterns (normal, concentric remodeling, concentric or eccentric hypertrophy) were calculated according to LV hypertrophy and relative wall thickness. Logistic regression analysis was used to determine odds ratio (OR) and 95% confidence interval (CI) of MS for LV hypertrophy and LV geometry abnormality. **Results:** The LV mass and LV mass index were higher in the MS group than in the non-MS group. In multiple adjusted models. LV mass index, LV mass, interventricular septum, and post wall were raised with the increased number of MS disorders. MS was associated with increased LV hypertrophy risk (unadjusted OR 1.38; 95% CI 1.21-1.57); age, sex, and blood pressure (BP; adjusted OR 1.39; 95% CI 1.22-1.59). MS was also associated with increased risk of eccentric hypertrophy in male and female patients. MS was only associated with increased risk of concentric hypertrophy in female patients; and MS was not associated with concentric remodeling. **Conclusion:** LV mass and LV mass index were associated with the increased number of MS disorders in the Chinese community-based hypertensive population. MS was not only associated with increased LV hypertrophy risk, but also associated with concentric and eccentric LV geometry abnormality, especially in females.

Key words: Hypertension, left ventricular (LV) geometry abnormality, LV hypertrophy, metabolic syndrome (MS)

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INTRODUCTION

Metabolic syndrome (MS) is associated with a twofold increase in the risk of coronary heart disease (CHD) and stroke events.[1] Echocardiographic hypertrophy is an independent risk factor of cardiac morbidity and mortality and all cause of mortality.[2,3]

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The association of MS with LV hypertrophy is controversial. A study in black women and men indicated that the degree of MS was strongly related to LV mass and its wall thickness components.[4] Another study conducetd in Native American concluded that in different components of the MS, only high blood pressure (BP) was associated with increased LV mass and prevalence of LV hypertrophy.[5] Recent studies indicated that the impact of

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MS on LV remodeling is significantly influenced by gender, and the metabolic sequence of MS is more important for LV remodeling in women.[6,7] The number of study subjects in previously was no more than 1572 in the Atherosclerosis Risk in Communities (ARIC) Study.[4] Because MS is a disease with at least three components of cardiovascular risk factors, the scale of the study samples could directly affect the results. This community-based study included 4106 subjects with or without MS.

Our purpose was to investigate the influence of MS on LV mass and geometry in community-based hypertensive patients among the Han Chinese.

MATERIALS AND METHODS

Study population

Details of our study protocol have been described previously.[8] Briefly, this community-based cross-sectional study was conducted in XinYang county, located in the central China, from 2004 to 2005. We used a multistage cluster sampling method to select a representative sample of rural community residents aged 40-75 years. The total 13,444 subjects (5270 men and 8174 women) underwent the survey, and yielded a response rate of 84.9%. Of them, 5421 hypertension patients were identified and thoroughly examined. Hypertension was defined as diastolic blood pressure (DBP) of ≥90 mmHg, systolic blood pressure (SBP) of ≥140 mmHg, physician diagnosis, or current medication for hypertension [as defined by the World Health Organization (WHO) 1999]. Laboratory tests were performed in the central laboratory included determinations of levels of serum sodium, potassium, creatinine, uric acid, blood urea nitrogen (BUN), total cholesterol, triglyceride, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and glucose.

The study protocol was reviewed and approved by the ethical committees of the FuWai Hospital and local hospitals. All participants gave their informed consent before they were recruited, and reported themselves to be of Han nationality. All investigators were trained at the Cardiovascular Institute, Chinese Academy of Medical Science (Beijing, China) and to be eligible by test.

The definition of metabolic syndrome

The definition of MS was defined with reference to the International Diabetes Federation (IDF) definition.[9] Asian central obesity: Waist circumference ≥90 cm for men, ≥80 cm for women, together with at least two of the following criteria:

1. Triglycerides level: ≥1.7 mmol/L or treatment for this abnormality;
2. HDL cholesterol (HDL-C): < 1.29 mmol/L for women or <1.03 mmol/L for men or treatment for this abnormality;
3. Hypertension: Arterial BP ≥130/85 mmHg or on antihypertensive medication;
4. Fasting plasma glucose: ≥5.6 mmol/L or previously diagnosed type 2 diabetes.

Echocardiographic methods

Transthoracic echocardiography was performed according to the standard protocol[10] that included M-mode, two-dimensional (2D), and color Doppler recordings from the parasternal long-axis and short-axis windows, as well as 2D and color Doppler evaluations from the apical window to yield 2-, 3-, and 4-chamber images with an HP 5500 (Phillips Medical System, Boston, Massachusetts, USA) or an HDI 3000 (ATL, Bothell, Washington, USA). The transducer frequency was 2.5-3.5 MHz. Optigo echocardiographic recorders (Agilent, Boston, Massachusetts, USA) were used occasionally to screen subjects who could not reach the local study center. The echocardiographic examination was supervised by two physician-echocardiographers with at least 2 years of experience. Two technicians from each center performed all the echocardiographic studies. Before the study, they were trained in the echocardiographic protocol at the Cardiovascular Institute, Chinese Academy of Medical Science.

Echocardiographic measurements

Correct orientation of planes for 2D and Doppler imaging was confirmed using standard procedures.[10] LV internal dimension and septal and posterior wall thicknesses were measured on up to three cardiac cycles at end-diastole and end-systole according to the American Society of Echocardiography recommendations.[10] Once optimal orientation of the LV views could not be obtained, as is common in subjects who are overweight or over age 60, correctly oriented 2D linear dimension measurements were made by the leading-edge convention of the American Society of Echocardiography.[10]

Calculation of derived variables

LV mass was calculated using the equation: $0.8 \times 1.04 [(IVS + LVEDD + PW)^3\text{-}LVEDD^3] + 0.6$, which yields values closely related ($R = 0.90$) to necropsy LV weight.[11] LV mass was divided by height$^{2.7}$ to obtain LV mass index (LVMI). RWT_m (relative wall thickness)[12] was calculated by (IVS + PW)/LVEDD, RWT_p [10] was calculated by 2 × PW/LVEDD, where IVS is interventricular septum, PW is posterior wall, and LVEDD is LV end-diastolic diameter. BSA (body surface area) was calculated by using the Du Bois formula:[13] $0.0071843 \times [\text{weight (kg)}]^{0.4253} \times [\text{height (cm)}]^{0.725}$ LVH was diagnosed by using the criteria of LVMI more than 49.2 g/m$^{2.7}$ for men and 46.7 g/m$^{2.7}$ for women.[14] A partition value of 0.43[14] was used for RWT_p and 0.45[15] for RWT_m, respectively.

Normal geometry was present when LVMI and RWT were normal, whereas normal LVMI and increased RWT identified concentric remodeling. Increased LVMI but normal RWT

identified eccentric LV hypertrophy, and increases of both variables identified concentric LV hypertrophy.[16]

Statistic analysis

SPSS software version 13.0 (SPSS, Inc. Chicago, Illinois, USA) was used for data management and statistical analysis. Data are reported as mean ± standard deviation (SD) for continuous variables and as frequency (percentage) for qualitative variables. Differences between proportions were assessed by x^2 test or Fisher's exact test. For continuous variables, differences between two groups were assessed by independent sample *t*-test; differences between multiple groups and analysis of covariance (ANCOVA) were performed by analysis of variance (ANOVA). A binary logistic regression model was used to determine the odds ratio (OR) of LVH and LV geometry for MS. Adjusted OR and 95% confidence intervals (CIs) were calculated. A two-tailed value of $P < 0.05$ was considered significant.

RESULTS

Clinical characteristics of the study population

Of 5421 hypertensive patients, 90% (N = 4869) underwent echocardiography, and 89% (N = 4805) were measured for LV mass. The patients with hypertrophic cardiomyopathy (N = 8), valvular heart diseases (N = 108), pulmonary hypertension (N = 7), and 412 patients with CHDs were excluded. Excluding the patients without reliable waist circumferences and lab test data (N = 164), a total of 4106 patients with integrated clinical and echocardiographic data were enrolled in the present study. The clinical characteristics of the study population were described in Table 1. This study comprised 1733 MS patients (1433 female patients and 298 male patients) and 2373 non-MS hypertension patients (1309 female patients and 1064 male patients).

MS and left ventricular mass

The echocardiographic data of the study population were described in Table 2. The LVEDD, PW, IVS, LV mass, and LVMI were higher in the MS group than in the non-MS group. In the ANCOVA adjusted for age and sex, the differences still remained, like the results in the model adjusted for age, sex, height, and waist circumference. RWT_m and RWT_p were no differences between the MS and non-MS groups in the unadjusted and adjusted models [Table 2].

According to the number of MS disorders (hypertension, central obesity, dyslipidemia, and glucose intolerance), the patients were categorized into four groups [Table 3]. LVMI, LVM, IVS, and PW were raised with the increasing number of MS disorders. In the model adjusted for age and sex, and that adjusted for age, sex, SBP, DBP, height, waist circumference, the differences still remained significant [Table 3].

MS was associated with increased LVH risk (unadjusted OR 1.38; 95% CI 1.21-1.57; age, sex-and BP-adjusted OR 1.39; 95% CI 1.22-1.59, in Table 4). This tendency was also

Table 1: Clinical characteristics of the study population

Clinical characteristics	Total (N = 4106)		Women (N = 2744)		Men (N = 1362)	
	MS (N = 1733)	Non-MS (N = 2373)	MS (N = 1435)	Non-MS (N = 1309)	MS (N = 298)	Non-MS (N = 1064)
Age (years)	58.26±8.40*	58.96±8.97	58.23±8.31	58.29±8.92	58.45±8.86*	59.79±8.98
SBP (mmHg)	164.84±24.86	164.53±24.56	165.39±25.13	165.54±24.76	162.17±23.43	163.29±24.26
DBP (mmHg)	98.47±12.99	98.04±12.73	98.21±13.04	97.95±13.21	99.75±12.74*	98.16±12.12
HR (beats/min)	74.61±12.24*	72.48±12.57	74.86±12.04*	73.17±11.64	73.38±13.14*	71.64±13.59
Glucose (mmol/L)	6.18±2.33*	5.25±1.43	6.17±2.41**	5.16±1.34	6.20±1.93**	5.36±1.54
Triglyceride (mmol/L)	2.64±1.61*	1.28±0.92	2.18±1.41**	1.22±0.65	2.53±2.32**	1.35±1.17
Cholesterol (mmol/L)	5.69±1.20*	5.37±1.04	5.69±1.21**	5.47±1.02	5.68±1.16**	5.24±1.06
HDL-C (mmol/L)	1.42±0.33*	1.63±0.35		1.71±0.34	1.37±0.29**	1.54±0.35

SBP = Systolic blood pressure; DBP = Diastolic blood pressure; HR = Heart rate; HDL-C = High-density lipoprotein cholesterol; MS = Metabolic syndrome; *MS vs non-MS; $P < 0.05$; **MS vs non-MS; $P < 0.01$

Table 2: The echocardiographic characteristics of patients with MS and without MS

Variables	Unadjusted			Adjusted*		
	MS (N = 1733)	Non-MS (N = 2373)	P	MS (N = 1733)	Non-MS (N = 2373)	P
LVEDD, mm	45.91±5.05	45.27±5.13	<0.001	45.96 (45.70,46.21)	45.25 (45.06,45.43)	<0.001
PW, mm	9.82±1.28	9.72±1.40	0.01	9.85 (9.78,9.92)	9.70 (9.65,9.75)	0.001
IVS, mm	10.18±1.55	9.93±1.60	<0.001	10.22 (10.14,10.30)	9.92 (9.86,9.98)	<0.001
LV mass, g	164.30±43.3	157.13±44.37	<0.001	165.23 (163.05,167.40)	156.63 (155.04,158.23)	<0.001
LVMI	48.13±12.51	46.04±12.48	<0.001	48.23 (47.58,48.87)	45.99 (45.51,46.46)	<0.001
RWT_m	0.44±0.08	0.44±0.08	0.53	0.44 (0.44,0.45)	0.44 (0.44,0.44)	0.26
RWT_p	0.43±0.07	0.43±0.08	0.57	0.43 (0.43,0.44)	0.43 (0.43,0.44)	0.87

MS = Metabolic syndrome; LVEDD = End-diastolic left ventricular internal dimension; PW = End-diastolic posterior wall thickness; IVS = End-diastolic interventricular septal thickness; LVMI = Left ventricular mass index divided by height 2.7; RWT_m = Relative wall thickness calculated by (IVS+PW)/LVEDD; RWT_p = Relative wall thickness calculated by 2 × PWTd/LVIDD; *Adjusted for age, sex, height (except for LVMI, for which height is not included in adjustment model), and waist circumference

observed in males and females. Among age strata, MS was a risk factor of LVH in the age group of 40-55 years as well as the age group of 55-74 years [Table 4].

MS and LV geometry abnormality

MSs were associated with increasing prevalence of concentric hypertrophy and eccentric hypertrophy [Table 5]. MS was associated with increased risk of concentric hypertrophy (unadjusted OR 1.44; 95% CI 1.21-1.72; multiple-adjusted OR 1.49; 95% CI 1.25-1.78) in the whole group and in the female patients (unadjusted OR 1.58; 95% CI 1.28-1.95; multiple-adjusted OR 1.63; 95% CI 1.31-2.02), but not with the male patients (unadjusted OR 1.11; 95% CI 0.80-1.53; multiple-adjusted OR 1.16; 95% CI 0.84-1.62). This risk remained coincident in the 40-55 years group (unadjusted OR 1.36; 95% CI 1.00-1.84; multiple-adjusted OR 1.36; 95% CI 1.00-1.84) and in the 55-74 years age group (unadjusted OR 1.54; 95% CI 1.24-1.92; multiple-adjusted OR 1.50; 95% CI 1.20-1.87).

MS was also associated with increased risk of eccentric hypertrophy (unadjusted OR 1.33; 95% CI 1.11-1.60; multiple-adjusted OR 1.38; 95% CI 1.15-1.65) in the whole group and in the female patients (unadjusted OR 1.31; 95% CI 1.05-1.63; multiple-adjusted OR 1.31; 95% CI 1.05-1.63), as well as the male patients (unadjusted OR 1.36; 95% CI 1.00-1.89; multiple-adjusted OR 1.45; 95% CI 1.03-2.02). This risk also remained coincident in the 40-55 years age group (unadjusted OR 1.37; 95% CI 1.03-1.82; multiple-adjusted OR 1.37; 95% CI 1.03-1.82) and in the 55-74 years age group (unadjusted OR 1.34; 95% CI 1.06-1.70; multiple-adjusted OR, 1.35; 95% CI 1.06-1.71).

However, MS was not associated with concentric remodeling regardless in the whole group, in the female and male groups, and in different age groups [Table 5].

Table 3: The echocardiographic characteristics of patients according to number of metabolic syndrome disorders

Variables	Hypertension only	Any 2	Any 3	All 4	*P*
LVMI,g/m$^{2.7}$					
Model 1	44.0±12.3	47.3±12.4	47.8±12.2	49.2±13.7	<0.001
Model 2	44.3±12.6	47.1±12.5	46.9±12.4	48.7±13.6	<0.001
LVM,g					
Model 1	149.7±44.3	161.7±43.8	163.3±42.2	167.8±47.1	<0.001
Model 2	149.9±44.2	160.4±44.2	162.7±42.8	166.5±48.2	<0.001
IVS,mm					
Model 1	9.7±1.6	10.0±1.6	10.2±1.5	10.3±1.6	<0.001
Model 2	9.8±1.6	10.1±1.6	10.2±1.5	10.3±1.6	<0.001
PW,mm					
Model 1	9.4±1.4	9.6±1.4	9.8±1.3	9.9±1.4	<0.001
Model 2	9.4±1.4	9.6±1.4	9.8±1.3	9.9±1.4	<0.001
LVEDD,mm					
Model 1	44.5±5.2	45.7±5.1	45.8±5.0	46.2±5.2	<0.001
Model 2	44.8±5.3	45.5±5.1	45.8±5.0	46.1±5.3	<0.001
RWT					
Model 1	0.44±0.1	0.44±0.1	0.44±0.1	0.44±0.1	NS
Model 2	0.43±0.1	0.44±0.1	0.43±0.1	0.44±0.1	NS

MS = Metabolic syndrome; LVMI = Left ventricular mass index divided by height 2.7; LVM = Left ventricular mass; Model 1 = Adjusted for age and sex; Model 2 = Adjusted for age; sex = Systolic blood pressure, diastolic blood pressure, height (except for LVMI, for which height is not included in adjustment model), and waist circumference

Table 4: The association of MS with LVH

Groups	Odds ratio of MS with LVH	
MS/non-MS	Unadjusted OR (95% CI)	Age-, sex-and BP-adjusted OR (95% CI)
Whole group	1.38 (1.21,1.57)	1.39 (1.22,1.59)
Male	1.25 (1.00,1.58)	1.34 (1.05,1.71)
Female	1.41 (1.21,1.64)	1.41 (1.21,1.65)
Age 40-55 years	1.31 (1.06,1.63)	1.28 (1.03,1.60)
Age 55-74 years	1.45 (1.24,1.71)	1.41 (1.20,1.67)

MS = Metabolic syndrome; LVH = Left ventricular hypertrophy; BP = Blood pressure

DISCUSSION

Our study results indicated that in our Chinese community-based hypertensive population, LV mass and LVMI were higher in the MS group than in the non-MS group adjusted by age, sex, height, and waist circumference. Furthermore, LV mass and LVMI were associated with the increasing number of MS disorders. In multiple-adjusted regression models, MS was not only associated with increased LVH risk, but also associated with concentric and eccentric LV geometry abnormality. Female MS patients carried higher risk for concentric and eccentric hypertrophy.

MS is a cluster of interrelated risk factors of metabolic origin that appear to directly promote the development of atherosclerotic cardiovascular disease.[17] The definitions of

Table 5: The association of metabolic syndrome with left ventricular geometry abnormality

Groups	Concentric hypertrophy (*N* = 927)		Eccentric hypertrophy (*N* = 829)		Concentric remodeling (*N* = 1014)	
	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)
Whole group	1.44 (1.21,1.72)	1.49 (1.25,1.78)	1.33 (1.11,1.60)	1.38 (1.15,1.65)	1.02 (0.86,1.22)	1.06 (0.89,1.26)
Male	1.11 (0.80,1.53)	1.16 (0.84,1.62)	1.36 (1.00,1.89)	1.45 (1.03,2.02)	0.95 (0.70,1.27)	0.98 (0.73,1.33)
Female	1.58 (1.28,1.95)	1.63 (1.31,2.02)	1.31 (1.05,1.63)	1.31 (1.05,1.63)	1.07 (0.86,1.32)	1.09 (0.88,1.36)
Age 40-55 years	1.36 (1.00,1.84)	1.36 (1.00,1.84)	1.37 (1.03,1.82)	1.37 (1.03,1.82)	1.11 (0.84,1.46)	1.09 (0.83,1.44)
Age 55-74 years	1.54 (1.24,1.92)	1.50 (1.20,1.87)	1.34 (1.06,1.70)	1.35 (1.06,1.71)	1.00 (0.79,1.25)	1.02 (0.81,1.27)

*Adjusted for age, sex, SBP, DBP

MS proposed by different organizations attempt to set forth simple diagnostic criteria to be used in clinical practice to identify patients who manifest the multiple components of MS.[18] The widely used definitions of MS in clinical settings including the National Cholesterol Education Program (NCEP) of the USA[19] and the International Diabetes Federation (IDF).[20] In this study, the IDF definition was used to diagnose MS because IDF recommended that the cutoff points for waist circumference be specific to an ethnic group; in addition, the previous study of our group indicated that the IDF-defined MS was more strongly associated with CHD than the NCEP definition.[21]

The formula used to calculate LVH is still a source of controversy. LV mass indexation was performed by a variety of different methods and PVs for men and women to diagnosis LVH. The values of $LVMI_{BSA}$ were 116 g/m^2 for men and 104 g/m^2 for women,[22] 125 g/m^2 for men and 110 g/m^2 for women,[23] 131 g/m^2 for men and 100 g/m^2 for women,[24] or 125 g/m^2 for men and women. The values of LVMI were 51 g/m$^{2.7}$ for men and women or 49.2 g/m$^{2.7}$ for men and 46.7 g/m$^{2.7}$ for women.[14] Different PVs lead to marked discrepancies in the prevalence of hypertrophy and the distribution of LV geometric patterns, which may affect the clinical treatment strategy of the patients. Our study indicated that the LV mass indexed by height$^{2.7}$ is more sensitive to diagnosis of LVH and LV mass/height$^{2.7}$ (49.2/46.7) was with increasing concomitant cerebrovascular diseases ($P < 0.05$).[25]

The results of the ARIC study indicated that LV mass and LVMI were associated with number of disorders in both women and men.[4] A previous study on a population of hypertensive patients showed that the relationship between MS and LV hypertrophy was not affected by gender.[25] Recent studies indicated that the metabolic sequence of MS is more important for LV remodeling in women.[6,7] In our study, MS was associated with increased LVH risk in both genders. Female MS patients carried higher risk for concentric and eccentric hypertrophy; male MS patients only had risk for eccentric hypertrophy. Our study supports that MS is more important for LV remodeling in women.

Our study population was a large community-based sample, and to our knowledge, this is the largest number for echocardiographic evaluation of LV mass, at least in Chinese. Another characteristic of our study subjects was that they were a community-based hypertension population enrolled in a rural area, which could avoid selection bias and better represent the Chinese hypertensive population. Furthermore, echocardiographic estimates of LV mass are more sensitive and specific than electrocardiography (ECG).[26] Last but not least, the definitions of MS and LVH were both based on our previous studies.

CONCLUSION

LV mass and LVMI were associated with the increasing number of MS disorders in a Chinese community-based hypertensive population. MS was not only associated with increased LVH risk but also associated with concentric and eccentric LV geometry abnormality, especially in females.

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Conflicts of interest

There are no conflicts of interest.

AUTHOR'S CONTRIBUTION

RH contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work, and agreed for all aspects of the work. JH contributed in the conception of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. SW contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. KS contributed in the conception of the work, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. XG contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. HX contributed in the conception of the work, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. NW contributed in the conception of the work, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. JC contributed in the design of the work, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. YZ contributed in the conception and design of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. KS contributed in the conception and design of the work, drafting and revising the

draft, approval of the final version of the manuscript, and agreed for all aspects of the work. HW contributed in the conception and design of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.

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