Independent Influence of Overweight and Obesity on the Regression of Left Ventricular Hypertrophy in Hypertensive Patients

A Meta-analysis

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Abstract: Overweight and obesity are associated with adverse cardiovascular outcomes. However, the role of overweight and obesity in left ventricular hypertrophy (LVH) of hypertensive patients is controversial. The aim of the current meta-analysis was to evaluate the influence of overweight and obesity on LVH regression in the hypertensive population.

Twenty-eight randomized controlled trials comprising 2403 hypertensive patients (mean age range: 43.8–66.7 years) were identified. Three groups were divided according to body mass index: normal weight, overweight, and obesity groups.

Compared with the normal-weight group, LVH regression in the overweight and obesity groups was more obvious with less reduction of systolic blood pressure after antihypertensive therapies (P < 0.001). The

KZ and FH contributed equally to this research.

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- We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work. We also declare that there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.
- KZ and FFH wrote the manuscript. HH and JFW contributed to the design of the individual trials. JC and QQC were responsible for statistical analysis. TW, RZ, and ZYZ were involved in the conduct/data collection and critical analysis, and shared in final responsibility for the content of the manuscript and the decision to submit it for publication.

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renin–angiotensin system inhibitor was the most effective in regressing LVH in overweight and obese hypertensive patients (19.27 g/m², 95% confidence interval [15.25, 23.29], P < 0.001), followed by β -blockers, calcium channel blockers, and diuretics. In the stratified analysis based on blood pressure measurement methods and age, more significant LVH regression was found in 24-h ambulatory blood pressure monitoring (ABPM) group and in relatively young patients (40–60 years' old) group (P < 0.01).

Overweight and obesity are independent risk factors for LVH in hypertensive patients. Intervention at an early age and monitoring by ABPM may facilitate therapy-induced LVH regression in overweight and obese hypertensive patients.

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Abbreviations: ABPM = ambulatory blood pressure monitoring, ACEI = angiotensin-converting enzyme inhibitors, ARB = angiotensin receptor blockers, β -blockers = beta-receptor blockers, BMI = body mass index, BP = blood pressure, CCB = calcium channel blockers, CI = confidence interval, DBP = diastolic blood pressure, LVM = left ventricular mass, LVH = left ventricular hypertrophy, LVMI = left ventricular mass index, RAS = renin-angiotensin system, RASI = renin-angiotensin system inhibitor, RCT = randomized control trial, SBP = systolic blood pressure, WHO = World Health Organization, WMD = weighted mean difference.

INTRODUCTION

verweight and obesity are a major health problem worldwide and lead to a large number of deaths annually.¹ Overweight and obesity are associated with left ventricular hypertrophy (LVH), which is a strong predictor of cardiovascular morbidity and mortality.² It is known that overweight and obesity not only are definitive risk factors for hypertension, but also play a key role in the process of LVH.³ Previous studies have shown that body mass index (BMI), the most commonly used index of adiposity, independently predicts left ventricular mass (LVM).⁴ Undergoing substantial weight loss through bariatric surgery and diet restriction reduced LVH in overweight and obese subjects independent of changes in blood pressure (BP).^{5,6} However, there are different viewpoints. Hsuan et al⁷ considered that BP reduction was the major determinant for the regression of LVH in the early stage of surgical weight reduction. In ob/ob mice, although caloric restriction induced weight loss, no decrease in wall thickness and a lesser change in myocyte size were found.⁸ Thus, the role

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of overweight and obesity in LVH is still under debate and is not known in hypertensive patients.

The aim of the present meta-analysis was mainly to evaluate the influence of overweight and obesity on LVH regression in hypertensive patients. Furthermore, previous studies have showed that different antihypertensive drugs have different antihypertrophic effect.9 Variant methods used for BP measurement are of different help to demonstrate the BP variability, which is pivotal for LVH. BP measurement methods such as office or clinic BP measurement and 24-h ambulatory BP monitoring were also found to have a close association with clinical cardiovascular outcomes in hypertensive patients.¹⁰ In addition, the ETODH study showed age is related with the prevalence of severe LVH in essential hypertension.¹¹ However, the influence of antihypertensive drugs, BP measurement methods, and age on LVH regression in overweight and obese hypertensive patients was not completely clear. So in the present study, we also explored the influence of these factors on LVH regression in overweight and obese patients with hypertension.

METHODS

Selection of Studies

We performed an electronic literature search of PubMed database since 1992 to January, 2013, using the terms "cardiac hypertrophy," "left ventricular hypertrophy," "LVH," "hypertension," "essential hypertension," "arterial hypertension," and "regression." We also searched the reference lists of articles for relevant titles. Selection criteria for inclusion in the meta-analysis were as follows: randomized controlled trials (RCTs) with parallel design; full-text articles published in peerreviewed journals; English-language publications; follow-up time ≥ 3 months; the age of the patients of all races were older than 19 years; LVM was measured by echocardiography. And left ventricular mass index (LVMI) that was calculated as LVM in grams divided by body surface area in square meters (the studies that normalized LVMI for height^{2.7} were excluded); reporting BMI at baseline; reporting LVMI at baseline and at the end of follow-up time; and all patients evaluated had treated or never-treated essential, nonmalignant hypertension.

Data Extraction and Quality Assessment

Two investigators independently reviewed all potentially eligible studies and the following data were collected: study design, name of the authors, name of the journal, year of the publication, sample size, age, sex ratio, follow-up time, type of drugs, systolic blood pressure (SBP), diastolic blood pressure (DBP), BP measurement methods, BMI, and LVMI at baseline and at the end of follow-up time. Discrepancies were resolved by reviewing the articles again to achieve consensus. Methodological quality was evaluated using the modified Jadad scale.¹² Eight-point scale was designed to assess the included RCTs. Scores of 4 to 8 denoted high quality, and scores of 0 to 3 represented low quality.

Statistical Analysis

Descriptive data of all participants are given the mean and range or median (minimum, maximum). Each RCT was composed of ≥ 2 treatment arms, and each type of treatment was taken as a separate observation, which made possible multivariate adjustments for differences in parameters (such as age, sex, BP, and LVMI at baseline) among BMI classification.

Continuous data were analyzed using weighted mean differences (WMDs) and 95% confidence intervals (CIs). We used fixed or random effects model to estimate the differences among groups according to the absence or presence of heterogeneity among studies. Statistical heterogeneity across studies was assessed using I^2 statistic with significance being set at $I^2 > 50\%$. Multivariable weighted metaregression was used to analyze the possible sources of heterogeneity. Unpaired *t* test and nonparametric test were used for comparisons between or among groups, respectively. Publication bias was evaluated by using funnel plots, Begg test, and Egger test. A 2-tailed P < 0.05was considered significant. Statistical analyses were performed using Stata version 12.0 (Stata Corp, College Station, TX).

RESULTS

Study Selection

A total of 28 RCTs^{13-40} with 2403 hypertensive patients were identified for inclusion from 6042 relevant publications. The flow of selecting studies for the meta-analysis was shown in Figure 1.

Baseline Characteristics and Study Quality

Table 1 summarized the baseline characteristics and study quality of the included trials. Sample size of the studies ranged from 24 to 411 participants, totaling 2403 participants.^{13–40} The average age ranged from 43.8 to 66.7 years, and men accounted for 23.7% to 100% in each study. The range of mean SBP at baseline was 144 to 189 mmHg, whereas the range of mean DBP was 86 to 106 mmHg. At baseline, the average BMI ranged from 19.5 to 30.5 g/m², whereas the echocardiographic hypertrophic indicator, LVMI, ranged from 98.2 to 163.5 g/m². Mean follow-up time was 10.4 months (range: 3–48 months), and the study quality score ranged from 3 to 7. Five types of antihypertensive drugs were used in studies: angiotensin-converting enzyme inhibitors (ACEI), angiotensin receptor blockers (ARB), calcium channel blockers (CCB), beta-receptor blockers (β-blockers), and diuretics. We grouped the studies

6042 relevant publications identified Limits: Human, RCT, English language, age ≥19 years 373 potential publications screened 282 excluded based on titles or abstracts 91 publications retrieved for detailed review 63 excluded based on the criteria: Follow-up time ≥3 months LVM evaluated by echocardiography LVMI normalized by body surface area in square meters Reporting BMI at baseline Reporting LVMI at baseline and at the end of follow-up time 28 RCTs included in this meta-analysis

FIGURE 1. Process of study selection. BMI = body mass index, LVM = left ventricular mass, LVMI = left ventricular mass index, RCT = randomized controlled trial.

Author (year)	n	Men, %	Mean Age, y	Mean Follow-up, month	Mean SBP, mmHg	Mean DBP, mmHg	Mean BMI, g/m ²	Mean LVMI, g/m ²	Type of Drugs	Modified Jadad Score
Dahlof and Hansson (1992) ¹³	28	100	46	16	155	102	27	125	ACEI, diuretics	4
Jula and Karanko (1994) ¹⁴	76	60.5	43.8	12	147	97	27.4	119	None	4
Diez and Laviades (1994) ¹⁵	87	57.5	47	6	_	_	29	102	ACEI	3
Grandi et al (1995) ¹⁶	36	50	44	6	156	106	24.8	140.5	ACEI, CCB	4
Schobel et al (1996) ¹⁷	43	67.4	52	6	146	94	27.8	145	β-blockers, other	4
Ueno et al (1997) ¹⁸	36	44.4	52	12	173	103	25.2	118.7	ACEI, CCB, other	4.5
Roman et al (1998) ¹⁹	50	74	51.2	6	150	95	27.8	98.2	ACEI, diuretics	4
Agabiti-Rosei et al (1998) ²⁰	32	56.3	50.4	6	157	101	27.8	141.8	CCB, diuretics	5
Martina and Lau (1999) ²¹	25	64	51	4	150	101	30.5	149.5	ARB, CCB	4
Cheung et al $(1999)^{22}$	33	60.6	49.5	3	153	96	25	115.4	ACEI	5
Gosse et al $(2000)^{23}$	411	56.4	54.5	12	172	101	26.8	140.9	ACEI, diuretics	5
Avanza et al $(2000)^{24}$	46	58.7	54	10	172	103	26.7	144.7	ACEI, ARB	4
Novo et al (2001) ²⁵	46	54.3	55	6	157	104	25.3	140.4	ACEI, β-blockers, diuretics	3
Skudicky et al (2002) ²⁶	173	23.7	51	4	151	97	30.3	118	ACEI, CCB	4
Cuspidi et al $(2002)^{27}$	196	62.2	53	12	163	101.3	26.2	142.2	ARB, ACEI	7
Takami and Shigematsu (2003) ²⁸	45	100	61.1	6	174	97	23.1	129.8	CCB	4
Sakata et al (2003) ²⁹	60	50	62	12	154	90	22.5	124.5	ACEI, CCB	3
Yasunari et al (2004) ³⁰	104	59.6	63	8	152	93	24.2	163.5	ARB, CCB	7
Rinder et al $(2004)^{31}$	28	82.1	65.9	6	154	91	30.2	118.2	diuretics	4
de Luca et al (2004) ³²	214	64.5	53.5	12	162	99	26.8	127.4	ACEI, β-blockers, diuretics	5
Bilge et al $(2005)^{33}$	27	63	48	6	144	96	26.4	120	ACEI, CCB	3
Anan et al $(2005)^{34}$	31	54.8	59	10	157	97	25.6	151.3	ACEI, ARB	3
Agabiti-Rosei et al (2005) ³⁵	174	60.3	53.3	48	160	100	27.3	104.9	CCB, β-blockers	5
Grandi et al (2008) ³⁶	24	79.2	49	6	145	94	28.6	150.5	ACEI, ARB, CCB	3
Takami and Saito (2011) ³⁷	50	70	66.7	6	152	86	25.8	122.8	ARB, CCB	4
Pan et al $(2011)^{38}$	41	61	64	12	189	101	24.8	129.5	ARB, other	4
Caglar and Dincer (2011) ³⁹	106	48.1	50.8	10	160	99	29.5	147.4	ACEI, β-blockers	5
Fogari et al (2012) ⁴⁰	181	51.4	64	12	147	92	27.2	132.7	ARB, CCB	5

TABLE 1. Baseline Characteristics and Study Quality of Study Population in 28 Trials (n = 2403)

ACEI = angiotensin-converting enzyme inhibitors, ARB = angiotensin receptor blockers, β -blockers = beta-receptor blockers, BMI = body mass index, CCB = calcium channel blockers, DBP = diastolic blood pressure, LVH = left ventricular hypertrophy, LVMI = left ventricular mass index, SBP = systolic blood pressure.

according to BMI classification of the World Health Organization (WHO) guideline⁴¹: normal weight $(18.5-24.9 \text{ kg/m}^2)$ group, overweight $(25-29.9 \text{ kg/m}^2)$ group, and obesity $(\geq 30 \text{ kg/m}^2)$ group. No significant difference in age, SBP, DBP, and LVMI at baseline was found among these 3 groups (Table 2).

LVH Regression in Different BMI Subgroups

Although the LVMI at baseline was consistent among the 3 BMI groups (Table 2), LVMI significantly decreased during the follow-up period: normal-weight group (WMD 13.78 g/m², 95% CI [9.06, 18.50], P < 0.001), overweight group (WMD 14.27 g/m², 95% CI [11.00, 17.54], P < 0.001], and obesity

TABLE 2. The Baseline Characteristics Among the 3 Body Mass Index Groups					
Baseline	Normal Weight	Overweight	Obesity	Р	
Age, y	60.9 (44-64)	53 (43.5-67.5)	51.5 (47-66.4)	0.13	
SBP, mmHg	155.6 (152–174)	155.4 (143–174)	152 (145–154)	0.14	
DBP, mmHg	96.8 (90-106)	97 (85.8–106)	98.5 (90-102)	0.63	
LVMI, g/m ²	129.9 (120.8–166)	128.2 (92.7–155)	128.2 (118–163)	0.37	

Values are expressed as median (minimum, maximum). P value showed the comparison of baseline characteristics among 3 body mass index groups. DBP = diastolic blood pressure, LVMI = left ventricular mass index, SBP = systolic blood pressure.

group (WMD 22.05 g/m², 95% CI [13.67, 30.44], P < 0.001) (Figure 2). The comparison among the 3 groups showed that the regression of LVH was the most obvious in obesity group, followed by overweight group and normal-weight group (P < 0.001).

SBP Reduction in Different BMI Subgroups

To explore whether LVMI regression is associated with the degree of SBP reduction, we analyzed SBP reduction in different BMI subgroups. Interestingly, although SBP at baseline showed no difference among the 3 groups (Table 2), SBP significantly reduced in normal-weight group (WMD 24.92 mmHg, 95% CI [16.46, 33.39], P < 0.001), followed by overweight group (WMD 20.34 mmHg, 95% CI [17.05, 23.6], P < 0.001), and obesity group (WMD 16.68 mmHg, 95% CI [10.79, 22.56], P < 0.001) (Figure 3). The comparison of SBP reduction among the 3 BMI subgroups was significant (P < 0.001).

DBP Reduction in Different BMI Subgroups

We also analyzed DBP reduction in different BMI subgroups. The results showed that all subgroups had a significant DBP reduction (P < 0.001, Figure 4). Both overweight group and obesity group had a larger DBP reduction than normal group (t=2.14, P=0.033; t=2.15, P=0.032, respectively). However, no significant difference was found between overweight group and obesity group (t=0.82, P=0.41).

Different Antihypertensive Drugs and the Regression of LVH in Overweight and Obese Hypertensive Patients

Different antihypertensive drugs exhibited different anti-LVH effect in overweight and obese hypertensive patients. As shown in Figure 5, the regression of LVH was 19.27 g/m^2 (WMD) (95% CI [15.25, 23.29], P < 0.001) in the renin– angiotensin system inhibitor (RASI) (ACEI/ARB) group, 17.81 g/m^2 (WMD) (95% CI [6.53, 29.09], P < 0.001) in β -blockers subgroup, 13.93 g/m^2 (WMD) (95% CI [9.66, 18.21], P < 0.001) in CCB subgroup, 7.94 g/m^2 (WMD) (95% CI [2.75, 13.13], P < 0.001) in diuretics subgroup, and 6.90 g/m^2 (WMD) (95% CI [3.30, 10.50], P < 0.001) in other treatment subgroup. We found that RASI was the most effective to induce LVH regression in overweight and obese patients with hypertension (P < 0.01).

Different BP Measurement Methods and the Regression of LVH in Overweight and Obese Hypertensive Patients

According to the BP measurement methods, we grouped the overweight and obese hypertensive patients into 2 groups: 24-h ambulatory BP monitoring (ABPM) group and office/clinic BP measurement group. More LVH regression was found in 24-h ABPM group comparing with office/clinic BP measurement group (18.56 vs 12.14 g/m^2 , P < 0.001) (Figure 6). This finding indicated that the degree of BP reduction measured by 24-h ABPM had a closer association with the level of LVH regression.

LVH Regression in Different Age Subgroups of Overweight and Obese Hypertensive Patients

Three age subgroups were divided according to the mean age in overweight and obese hypertensive patients: G1, 40 to

49 years' old; G2, 50 to 59 years' old; and G3, age \geq 60 years' old. As shown in Figure 7, all 3 groups had a significant LVH regression: G1 (WMD 13.09 g/m², 95% CI [6.96, 19.23.39], P < 0.001), G2 (WMD 14.93 g/m², 95% CI [10.83, 19.04], P < 0.001), and G3 (WMD 12.36 g/m², 95% CI [5.98, 18.72], P < 0.001). G3 (age \geq 60 years' old) group showed a less LVMI regression comparing with the other 2 groups (P < 0.01). Furthermore, we explored the changes of SBP and DBP in different age subgroups. It was found that BP decreased most in G3 group, followed by G1 and G2 groups (Table 3). The above results indicated that obesity influenced LVH regression independent of BP reduction in the aged population (age \geq 60 years' old).

Determinants for the Heterogeneity Among the Studies

Table 4 gave the results of the multivariable metaregression analysis to identify the potential determinants for statistical heterogeneity among studies. Both BP measurement methods and LVMI at baseline contributed to the statistical heterogeneity (BP measurement methods, P = 0.017; LVMI at baseline, P = 0.023, Table 4). However, factors like age, follow-up time, sample size, study quality, BP, and type of drugs showed no contributions (P > 0.05, Table 4).

Publication Bias

When we explored for potential publication bias, the funnel plot did not appear asymmetrically (Figure 8), and no significant difference was found in the Begg and Egger test (Begg test, P = 0.38; Egger test, P = 0.10).

DISCUSSION

The main findings of this current meta-analysis were that the regression of LVH during the follow-up time was the most obvious in overweight and obese hypertensive patients. The degree of LVH regression was not in the same ranking order of the BP reduction. RASI was the most effective antihypertensive drug for LVH regression in overweight and obese hypertensive patients. The 24-h ABPM method was more useful to guide BP controlling to reflect LVH regression in overweight and obese hypertensive patients. Furthermore, in overweight and obese hypertensive patients, older age (age ≥ 60 years) was also an influencing factor for the reduction of LVH.

LVH is a definite cardiac damage in hypertensive patients and associates with a series of cardiovascular events.² Overweight and obesity are also important risk factors for cardiovascular diseases such as heart failure and hypertension. 42,43 Thus, if a person simultaneously had overweight/obesity and LVH, the incidence of cardiovascular events will be significantly increased. It was found that overweight and obese hypertensive patients had an absolute LVM 15% to 41% higher than that in a reference normal group of normal-weight normotensive subjects, independent of sex and SBP.44 In the present study, no difference of LVMI at baseline between overweight/ obese patients and normal-weight patients may because there are many factors determinate the LVM such as race, the duration of hypertension, etc.^{45,46} Our results showed that after adjustment of the BP and LVMI at baseline, the regression of LVH was the most obvious in overweight and obese hypertensive patients and was not accompanied with the degree of SBP reduction. It suggested that overweight and obesity might be the independent risk factors for LVH. And during the treatment for

Study ID	WMD (95% CI)	% Weight
Normal weight Grandi AM (1995) Grandi AM (1995) Cheung BM (1999) Takami T (2003) Takami T (2003) Sakata K (2003) Sakata K (2003) Yasunari K (2004) Yasunari K (2004) Pan XD (2011) Subtotal (I-squared = 70.1%, P = 0.000)	$\begin{array}{c} 20.00 \ (9.18, \ 30.82) \\ 30.00 \ (19.10, \ 40.90) \\ 11.80 \ (7.29, \ 16.31) \\ 3.20 \ (-2.96, \ 9.36) \\ 8.50 \ (2.20, \ 14.80) \\ 11.00 \ (5.76, \ 16.24) \\ 12.00 \ (1.88, \ 22.12) \\ 15.00 \ (0.69, \ 29.31) \\ 29.00 \ (18.41, \ 39.59) \\ 3.00 \ (-11.61, \ 17.61) \\ 15.26 \ (-3.72, \ 34.24) \\ 13.78 \ (9.06, \ 18.50) \end{array}$	8.34 8.29 13.08 11.86 11.75 12.55 8.83 6.28 8.51 6.13 4.37 100.00
Overweight Dahlof B (1992) Dahlof B (1992) Jula AM (1994) Jula AM (1994) Jule J (1992) Diez J (1992) Diez J (1992) Diez J (1992) Diez J (1992) Diez J (1992) Ueno H (1997) Ueno H (1997) Ueno H (1997) Ueno H (1997) Roman MJ (1998) Agabiti-Rosei E (1998) Agabiti-Rosei E (1998) Agabiti-Rosei E (1998) Agabiti-Rosei E (1998) Avanza AC (2000) Avanza AC (2002) Cuspidi C (2002) Cu	$\begin{array}{c} 21.60 \ (0.47, 42.73) \\ 13.30 \ (-10.32, 36.92) \\ 6.00 \ (-4.83, 16.83) \\ -1.00 \ (-11.12, 9.12) \\ 13.00 \ (-1.13, 27.13) \\ 15.00 \ (0.87, 29.13) \\ 11.00 \ (-4.30, 26.30) \\ 14.00 \ (-3.25, 31.25) \\ 15.00 \ (-1.11, 31.11) \\ -1.4.00 \ (20.99, 48.99) \\ 29.00 \ (4.20, 53.80) \\ -28.00 \ (-50.84, -5.16) \\ 8.70 \ (-5.18, 20.58) \\ 0.80 \ (-10.55, 12.15) \\ 0.80 \ (-10.55, 12.15) \\ 0.80 \ (-10.55, 12.15) \\ 1.00 \ (-12.9, 37.29) \\ -3.10 \ (-8.99, 2.79) \\ 8.30 \ (1.07, 15.53) \\ 1.90 \ (-5.23, 9.03) \\ 18.00 \ (15.31, 20.69) \\ 14.00 \ (11.61, 16.39) \\ 30.00 \ (27.55, 32.45) \\ 22.00 \ (12.36, 31.64) \\ 10.00 \ (-3.15, 23.15) \\ 27.00 \ (19.31, 34.69) \\ 18.00 \ (10.31, 25.69) \\ 14.00 \ (11.51, 20.85) \\ 15.00 \ (6.70, 23.30) \\ 13.30 \ (5.61, 20.99) \\ 16.70 \ (-6.41, 39.81) \\ 6.61 \ (-0.06, 13.28) \\ 2.04 \ (-4.51, 8.59) \\ 17.00 \ (-2.53, 35.47) \\ 35.00 \ (26.57, 43.43) \\ 13.70 \ (7.19, 20.21) \\ 13.30 \ (6.21, 20.39) \\ 33.00 \ (13.04, 70) \\ 36.25 \ (7.96, 64.54) \\ 14.80 \ (5.98, 23.62) \\ 26.10 \ (20.91, 31.29) \\ 13.40 \ (7.15, 19.65) \\ 14.27 \ (11.00, 17.54) \\ \end{array}$	$\begin{array}{c} 1.33\\ 1.17\\ 2.24\\ 2.31\\ 1.91\\ 1.91\\ 1.91\\ 1.80\\ 1.63\\ 1.73\\ 0.68\\ 1.10\\ 1.21\\ 2.14\\ 2.19\\ 1.29\\ 1.46\\ 2.71\\ 2.60\\ 2.61\\ 2.91\\ 2.93\\ 2.92\\ 2.36\\ 2.01\\ 2.55\\ 2.55\\ 2.34\\ 2.55\\ 2.55\\ 1.20\\ 2.65\\ 2.66\\ 1.61\\ 1.86\\ 2.05\\ 2.65\\ 2.66\\ 2.61\\ 1.88\\ 1.81\\ 2.95\\ 2.95\\ 0.92\\ 2.44\\ 2.77\\ 2.68\\ 100.00\\ \end{array}$
Obesity Martina B (1999) Martina B (1999) Skudicky D (2002) Rinder MR (2002) Caglar N (2011) Subtotal (I-squared = 39.8%, P = 0.156) NOTE: Weights are from random effects analysis	30.00 (-5.01, 65.01) 10.00 (-8.15, 28.15) 19.00 (10.95, 27.05) 16.80 (-5.62, 39.22) 31.90 (22.29, 41.51) 22.05 (13.67, 30.44)	5.20 15.36 36.42 11.15 31.87 100.00
-65 0	65	

FIGURE 2. LVH regression in different BMI subgroups. BMI = body mass index, CI = confidence interval, LVH = left ventricular hypertrophy, WMD = weighted mean difference.

Study ID	WMD (95% CI)	% Weight
Normal weight Grandi AM (1995) Grandi AM (1995) Cheung BM (1999) Takami T (2003) Takami T (2003) Takami T (2003) Sakata K (2003) Sakata K (2003) Yasunari K (2004) Yasunari K (2005) Yasunari K (2005) Yasunari K (2007) Yasunari K	 ◆ (1.04) (2.00) (15.43, 24.57) (1.04) (2.28) (1.04) (2.296) (21.00) (15.23, 26.77) (12.00) (9.69, 14.31) (1.04) (2.00) (9.69, 14.31) (2.00) (9.69, 14.31) (2.00) (16.46, 33.39) 	9.13 9.13 9.21 9.33 9.30 8.97 8.99 9.28 9.32 8.02 100.00
Overweight Dahlof B (1992) Dahlof B (1992) Jula AM (1994) Schobel HP (1996) Schobel HP (1996) Ueno H (1997) Ueno H (1997) Ueno H (1997) Agabiti-Rosei E (1998) Agabiti-Rosei E (1998) Cheung BM (1999) Novo S (2001) Novo S (2001) Novo S (2001) Novo S (2001) Novo S (2001) Skudicky D (2002) Rinder MR (2004) de Luca N (2004) de Luca N (2004) Bilge AK (2005) Bilge AK (2005) Anan F (2005) Anan F (2005) Anan F (2005) Anan F (2005) Agabiti-Rosei E (2005) Agabit-Rosei E (2005) Agabi	$\begin{array}{c} 19.50 \ (-22.89, 61.89) \\ 17.30 \ (-6.33, 40.93) \\ 15.50 \ (9.39, 21.61) \\ 8.80 \ (3.95, 13.65) \\ 11.00 \ (4.35, 17.65) \\ 14.00 \ (4.35, 17.65) \\ 14.00 \ (4.35, 23.65) \\ 33.00 \ (24.16, 41.84) \\ 33.00 \ (22.43, 43.57) \\ 31.00 \ (21.22, 40.88) \\ 16.00 \ (10.27, 21.73) \\ 10.50 \ (3.48, 17.52) \\ -5.30 \ (-7.97, -2.63) \\ 30.00 \ (20.32, 39.68) \\ 18.00 \ (8.32, 27.68) \\ 19.00 \ (10.51, 27.49) \\ 23.00 \ (17.97, 28.03) \\ 26.60 \ (20.50, 32.70) \\ 21.30 \ (17.48, 25.12) \\ 15.30 \ (10.00, 20.60) \\ 19.00 \ (14.06, 23.94) \\ 16.00 \ (10.12, 21.88) \\ 23.00 \ (16.61, 29.39) \\ 24.00 \ (16.77, 31.23) \\ 20.60 \ (17.13, 24.07) \\ 22.50 \ (19.26, 25.74) \\ 20.00 \ (12.75, 27.25) \\ 19.00 \ (13.34, 24.66) \\ 15.10 \ (12.59, 17.61) \\ 14.50 \ (12.41, 16.59) \\ \end{array}$	0.51 1.25 3.11 3.24 3.05 2.68 2.79 2.56 2.65 3.15 3.01 3.41 2.68 2.68 2.78 2.83 3.22 3.11 3.33 3.20 3.23 3.14 3.11 3.08 2.98 3.36 3.37 2.98 3.16 3.42 3.44
Pan XD (2011) Fogari R (2012) Fogari R (2012) Subtotal (I-squared = 93.1%, P = 0.000) Obesity Martina B (1999) Martina B (1999) Skudicky D (2002) Rinder MR (2002) Subtotal (I-squared = 59.2%, P = 0.062)	62.96 (53.41, 72.51) 19.70 (16.67, 22.73) 20.50 (17.63, 23.37) 20.34 (17.05, 23.63) 22.00 (9.53, 34.47) 11.00 (1.99, 20.01) 21.00 (17.15, 24.85) 12.20 (4.79, 19.61) 16.68 (10.70, 22.5 E)	2.69 3.39 3.40 100.00 14.84 21.76 37.33 26.07 100.00
NOTE: Weights are from random effects analysis	10.00 (10.79, 22.50)	100.00
-72.5 0	72.5	

FIGURE 3. SBP reduction in different BMI subgroups. BMI = body mass index, CI = confidence interval, SBP = systolic blood pressure, WMD = weighted mean difference.

regression of LVH, we should pay more attention to the body weight control. However, to what extent an increase in LVM directly resulting from overweight and obesity is unclear. We observed that SBP reduction was less in overweight and obese hypertensive patients, whereas the reduction of DBP was higher in overweight and obese hypertensive patients. This discrepancy may indicate that DBP reduction contributes more to the regression of LVH.¹² Overweight and obesity are conditions of increased adipose tissue mass. An excess of body fat requires a high cardiac output to meet the metabolic demand. When this hemodynamic burden is sustained, LVH will form.⁴⁷ Insulin resistance is considered to be another important

Study ID	WMD (95% CI)	% Weight
Normal weight Grandi AM (1995) Grandi AM (1995) Cheung BM (1999) Takami T (2003) Takami T (2003) Takami T (2003) Sakata K (2003) Sakata K (2003) Yasunari K (2004) Yasunari K (2004) Pan XD (2011) Subtotal (I-squared = 91.7%, <i>P</i> = 0.000)	14.00 (9.74, 18.2 14.00 (10.39, 17 5.10 (3.30, 6.90) 15.00 (13.40, 16 14.00 (12.40, 15 14.00 (12.40, 15) 14.00 (17.74, 16 11.00 (7.00, 15.0 13.00 (8.03, 17.9 7.00 (5.08, 8.92) 8.00 (5.88, 10.12 20.77 (12.91, 28 11.92 (9.30, 14.5)	6) 8.35 61) 8.91 10.22 60) 60) 10.32 60) 10.32 60) 10.32 70) 8.58 77) 7.73 10.15 10.03 .63) 5.44 53) 100.00
Overweight Dahlof B (1992) Dahlof B (1992) Jula AM (1994) Schobel HP (1996) Schobel HP (1997) Ueno H (1997) Ueno H (1997) Jula AM (1994) Agabiti-Rosei E (1998) Agabiti-Rosei E (1998) Agabiti-Rosei E (1998) Cheung BM (1999) Novo S (2001) Skudicky D (2002) Rinder MR (2004) de Luca N (2004) de Luca N (2005) Anan F (2005) Anan F (2005) Anan F (2005) Agabiti-Rosei E (2005) Grandi AM	15.10 (0.17, 30.0 11.00 (-7.14, 29 8.80 (6.15, 11.4 5.00 (2.79, 7.21) 9.00 (4.79, 13.21 12.00 (1.34, 16.6 17.00 (10.99, 23 17.00 (11.34, 22 19.00 (13.40, 24 14.00 (10.42, 17 8.00 (5.23, 10.77) -1.10 (-2.81, 0.6 21.00 (14.41, 27 16.00 (8.99, 23.0 20.00 (14.47, 73 11.60 (6.40, 16.6 12.10 (9.75, 18.2 4.00 (-0.73, 8.7 11.60 (6.40, 16.6 12.10 (9.97, 14.2) 11.30 (10.66, 15 15.00 (10.86, 19) 12.00 (5.86, 18.1) 12.00 (13.8, 16.6 13.00 (6.41, 19.5 15.00 (13.8, 16.6 13.00 (6.41, 19.5 15.00 (13.8, 16.6 13.00 (6.41, 19.5 15.00 (13.8, 16.6 13.00 (6.41, 19.5 15.00 (13.8, 16.7) 22.30 (14.18, 17) 22.30 (14.18, 17) 22.30 (14.18, 17) 12.46 (10.25, 14)	3) 1.34 14) 1.04) 3.29 .3.34) 3.07 :6) 2.99 01) 2.75 :66) 2.82 :60) 2.83 :58) 3.17) 3.28 :11) 2.56 :13) 2.91 :59) 2.64 :11) 2.56 :13) 2.91 :50) 3.06 :0) 2.98 :00) 2.90 :33 3.35 :40) 3.08 :41) 3.08 :41) 3.08 :41) 2.73 :22) 3.00 :99) 2.64 :66) 3.38 :38) 3.41 :11) 2.75 :22) 2.90 3.32 3.32 :333 3.44 :44) 2.35 :84) 3.38 <td:62)< td=""> 3.38 <</td:62)<>
Obesity Martina B (1999) Martina B (1999) Skudicky D (2002) Rinder MR (2002) Subtotal (I-squared = 0.0%, <i>P</i> = 0.534) NOTE: Weights are from random effects analysis	14.00 (1.64, 20.3 14.00 (9.49, 18.5 12.00 (9.86, 14.1 8.90 (3.08, 14.72 12.18 (10.41, 13	i6) 7.67 i1) 15.31 4) 67.84 2) 9.17 .94) 100.00
Г -30.4	1 I 0 30.4	

FIGURE 4. DBP reduction in different BMI subgroups. BMI = body mass index, CI = confidence interval, DBP = diastolic blood pressure, WMD = weighted mean difference.

determinant for LVH in overweight and obese patients. It can lead to LVH through its growth-stimulating effect, increased sodium reabsorption in kidney, etc.⁴⁸ Both obesity and insulin resistance are the characteristics of metabolic syndrome (MetS). A previous study showed that BMI, but not the age and SBP, is the driving factor behind MetS-related LVM increase.⁴⁹ Furthermore, other risk factors such as neurohormonal activation⁵⁰ and increased inflammatory cytokines⁵¹ are all reported to be involved in the process of LVH in obesity. However, the dominant mechanism is still unknown.

Study ID	WMD (95% CI)	% Weight
Others Jula AM (1994) Jula AM (1994) Jula AM (1994) Schobel HP (1996) Ueno H (1997) Cheung BM (1999) Skudicky D (2002) Skudicky D (2002) Rinder MR (2004) de Luca N (2004) Grandi AM (2008) Takami T (2011) Takami T (2011) Pan XD (2011) Subtotal (I-squared = 74.7%, P = 0.000)	$\begin{array}{l} 6.00 & (-4.83, 16.83) \\ -1.00 & (-11.12, 9.12) \\ 14.00 & (-3.25, 31.25) \\ -28.00 & (-50.84, -5.16) \\ -3.10 & (-8.99, 2.79) \\ 14.00 & (4.15, 23.85) \\ 19.00 & (10.95, 27.05) \\ 16.80 & (-5.62, 39.22) \\ 16.70 & (-6.41, 39.81) \\ 6.61 & (-0.05, 13.28) \\ 19.00 & (3.78, 34.22) \\ 6.60 & (4.85, 8.35) \\ 3.00 & (1.30, 4.70) \\ \end{array}$	6.63 7.18 3.45 2.16 11.50 7.40 9.08 2.23 2.11 10.58 4.18 16.00 16.03 1.47 100.00
RASI Dahlof B (1992) Diez J (1994) Diez J (1994) Diez J (1994) Ueno H (1997) Roman MJ (1998) Martina B (1999) Gosse P (2000) Avanza AC (2000) Novo S (2001) Cuspidi C (2002) Bilge AK (2005) Anan F (2005) Anan F (2005) Grandi AM (2008) Caglar N (2011) Fogari R (2012) Subtotal (I-squared = 86.1%, <i>P</i> = 0.000)	$\begin{array}{c} 21.60 \ (0.47, 42.73) \\ 13.00 \ (-1.13, 27.13) \\ 15.00 \ (0.87, 29.13) \\ 11.00 \ (-4.30, 26.30) \\ 29.00 \ (4.20, 53.80) \\ 8.70 \ (-3.18, 20.58) \\ \hline \\ 30.00 \ (-5.01, 65.01) \\ 1.90 \ (-5.23, 9.03) \\ 18.00 \ (15.31, 20.69) \\ 14.00 \ (11.61, 16.39) \\ 30.00 \ (27.55, 32.45) \\ 22.00 \ (12.35, 31.64) \\ 18.00 \ (10.31, 25.69) \\ 15.00 \ (6.70, 23.30) \\ 13.30 \ (5.61, 20.99) \\ 17.00 \ (2.36, 31.64) \\ 27.00 \ (14.22, 39.78) \\ 24.00 \ (12.53, 35.47) \\ 35.00 \ (26.57, 43.43) \\ 33.00 \ (18.58, 47.42) \\ 14.80 \ (5.98, 23.62) \\ 26.10 \ (20.91, 31.29) \\ 19.27 \ (15.25, 23.29) \end{array}$	$\begin{array}{c} 2.37\\ 3.72\\ 3.45\\ 1.90\\ 4.30\\ 1.11\\ 5.66\\ 6.68\\ 6.73\\ 6.72\\ 4.93\\ 5.50\\ 5.33\\ 5.50\\ 5.33\\ 5.50\\ 3.60\\ 4.06\\ 4.41\\ 5.29\\ 3.65\\ 5.17\\ 6.18\\ 100.00\\ \end{array}$
CCB Ueno H (1997) Agabiti-Rosei E (1998) Martina B (1999) Bilge AK (2005) Agabiti-Rosei E (2005) Fogari R (2012) Subtotal (I-squared = 0.0%, P = 0.878)	$\begin{array}{c} 14.00 \ (-20.99, \ 48.99) \\ 27.15 \ (5.48, \ 48.82) \\ 10.00 \ (-8.15, \ 28.15) \\ 17.00 \ (-0.51, \ 34.51) \\ 13.30 \ (6.21, \ 20.39) \\ 13.40 \ (7.15, \ 19.66) \\ 13.93 \ (9.66, \ 18.21) \end{array}$	1.49 3.89 5.55 5.97 36.35 46.75 100.00
β-blockers Schobel HP (1996) Novo S (2001) de Luca N (2004) Agabiti-Rosei E (2005) Caglar N (2011) Subtotal (I-squared = 89.0%, P = 0.000)	15.00 (-1.11, 31.11) 27.00 (19.31, 34.69) 2.04 (-4.51, 8.59) 13.70 (7.19, 20.21) 31.90 (22.29, 41.51) 17.81 (6.53, 29.09)	15.79 21.03 21.61 21.63 19.94 100.00
Diretics Dahlof B (1992) Roman MJ (1998) Agabiti-Rosei E (1998) Gosse P (2000) Novo S (2001) Subtotal (I-squared = 0.0%, P = 0.580) NOTE: Weights are from random effects analysis	13.30 (-10.32, 36.92) 0.80 (-10.55, 12.15) 18.00 (-1.29, 37.29) 8.30 (1.07, 15.53) 10.00 (-3.15, 23.15) 7.94 (2.75, 13.13)	4.82 20.88 7.23 51.50 15.56 100.00
	Т 65	

FIGURE 5. Different antihypertensive drugs and the regression of LVH in overweight and obese hypertensive patients. β -blockers = betareceptor blockers, CCB = calcium channel blockers, CI = confidence interval, LVH = left ventricular hypertrophy, RASI = renin-angiotensin system inhibitor, WMD = weighted mean difference.

Study ID	WMD (95% CI)	% Weight
Office/clinic BD measurement		
Dablef R (1002)	21 60 (0 47 42 72)	1 97
Dahlof B (1992)	13 30 (-10 32 36 92)	1.60
Jula AM (1994)	6.00 (-4.83, 16.83)	3.67
Jula AM (1994)	-1 00 (-11 12 9 12)	3.83
Ueno H (1997)	– 14.00 (–20.99, 48.99)	0.87
Ueno H (1997)	29.00 (4.20, 53.80)	1.50
Ueno H (1997)	-28.00 (-50.84, -5.16)	1.68
Agabiti-Rosei E (1998)	- 27.15 (5.48, 48.82)	1.81
Agabiti-Rosei E (1998)	18.00(-1.29, 37.29)	2.10
Martina B (1999)	30.00 (-5.01, 65.01)	0.87
Martina B (1999)	10.00 (-8.15, 28.15)	2.26
Cheung BM (1999)	-3.10 (-8.99, 2.79)	4.83
Gosse P (2000)	8.30 (1.07, 15.53)	4.53
Gosse P (2000)	1.90 (-5.23, 9.03)	4.55
Novo S (2001)	22.00 (12.36, 31.64)	3.95
Novo S (2001)	10.00 (-3.15, 23.15)	3.16
Novo S (2001)	27.00 (19.31, 34.69)	4.42
Novo S (2001)	18.00 (10.31, 25.69)	4.42
	15.00 (6.70, 23.30)	4.27
	13.30 (5.61, 20.99)	4.42
de Luca N (2004)	6.61 (-0.06, 13.28)	4.66
ue Luca IN (2004)	2.04 (-4.51, 8.59)	4.08
Takami T (2011)	3.00 (1.30, 4.70)	5.50
Pan XD (2011)	36.25 (7.96, 64, 54)	1.23
Cadlar N (2011)	1/ 80 (5 98, 23 62)	1.20
Caglar N (2011)	31 90 (22 29 41 51)	3.96
Fogari B (2012)	26 10 (20 91 31 29)	4 98
Fogari B (2012)	13 40 (7 15 19 65)	4 75
Subtotal (I-squared = 85.9% , $P = 0.000$)	12.14 (8.59, 15.68)	100.00
24 h ambulatory BP monitoring		
Schobel HP (1996)	14 00 (-3 25, 31 25)	3 40
Schobel HP (1996)	1500(-1113111)	3.66
Roman MJ (1998)	8.70 (-3.18, 20.58)	4.84
Roman MJ (1998)	0.80 (-10.55, 12.15)	5.00
Avanza AC (2000)	18.00 (15.31, 20.69)	7.59
Avanza AC (2000)	14.00 (11.61, 16.39)	7.63
Avanza AC (2000)	30.00 (27.55, 32.45)	7.62
Skudicky D (2002)	14.00 (4.15, 23.85)	5.49
Skudicky D (2002)	19.00 (10.95, 27.05)	6.10
Rinder MR (2004)	16.80 (-5.62, 39.22)	2.45
Rinder MR (2004)	16.70 (–6.41, 39.81)	2.34
Bilge AK (2005)	17.00 (–0.51, 34.51)	3.34
Bilge AK (2005)	17.00 (2.36, 31.64)	4.04
Anan F (2005)	27.00 (14.22, 39.78)	4.56
Anan F (2005)	24.00 (12.53, 35.47)	4.96
Anan F (2005)	35.00 (26.57, 43.43)	5.97
Agabiti-Hosei E (2005)	13.70 (7.19, 20.21)	6.60
Ayabili-husel E (2003)		0.41
	- 33.00 (18.58, 47.42)	4.10
Gianui Aivi (2000) Subtotal / Leguerod = 95.6% P = 0.000	18.00 (3.78, 34.22)	3.00 100.00
	10.00 (14.02, 22.70)	100.00
INU I E: weights are from random effects analysis		
	65	
	00	

FIGURE 6. Different BP measurement methods and the regression of LVH in overweight and obese hypertensive patients. BP = blood pressure, CI = confidence interval, LVH = left ventricular hypertrophy, WMD = weighted mean difference.

The benefit effect of antihypertensive drugs for LVH regression has been studied extensively. It was found that different antihypertensive drugs had different antihypertrophic effect.^{9,52} As for overweight and obese hypertensive patients, there is still a lack of guideline for treating LVH. In the present study, we found that RASI was the most effective

antihypertensive drug for regressing LVH in overweight and obese hypertensive patients, which is consistent with recent viewpoints that RASI is considered to be the most appropriate drugs for antihypertensive treatment of obese patients for their possible benefit that they unlikely worsen glucose or lipid metabolism.⁵³ Activation of the renin–angiotensin system

Study ID	WMD (95% CI)	% Weight
G1: 40 to 49 years old		4 97
Dahlof B (1992)		4.07
Jula AM (1994)	6 00 (-4 83 16 83)	8.50
Jula AM (1994)	-1.00 (-11.12, 9.12)	8.79
Diez J (1992)	13.00(-1.13, 27.13)	7.16
Diez J (1992)	◆ 15.00 (0.87, 29.13)	7.17
Diez J (1992)	11.00 (-4.30, 26.30)	6.73
Schobel HP (1996)	◆ 14.00 (-3.25, 31.25)	6.04
Agabiti-Rosei E (1998)	27.15 (5.48, 48.82)	4.73
Martina B (1999)	♦ 30.00 (-5.01, 65.01)	2.43
Cheung BM (1999)	3.10 (-8.99, 2.79)	10.44
Skudicky D (2002)		8.90
Bilge AK (2005)		5.95
Bilge AK (2005) Grandi AM (2008)		0.97
Subtotal (Lequared = 65.5% $R = 0.000$)		100.00
Subiolal (I-Squared = 05.5% , $F = 0.000$)	13.09 (0.90, 19.23)	100.00
G2: 50 to 59 years old	15.00(1.11.21.11)	2.02
Lleno H (1997)		2.92
Lieno H (1997)		1.00
Ueno H (1997)	-28 00 (-50 84 -5 16)	2.01
Roman MJ (1998)	8.70 (-3.18, 20.58)	3.68
Roman MJ (1998)	0.80 (-10.55, 12.15)	3.78
Agabiti-Rosei E (1998)	◆ 18.00 (-1.29, 37.29)	2.44
Martina B (1999)	10.00 (-8.15, 28.15)	2.60
Gosse P (2000)	8.30 (1.07, 15.53)	4.56
Gosse P (2000)	↓ 1.90 (−5.23, 9.03)	4.58
Avanza AC (2000)	18.00 (15.31, 20.69)	5.19
Avanza AC (2000)		5.22
Avanza AC (2000) Skudialay D (2002)		5.21
Cuspidi C (2002)		4.41
Cuspidi C (2002)	13.30 (5.61, 20.99)	4 48
de Luca N (2004)	6.61 (-0.06, 13.28)	4.66
de Luca N (2004)	2.04 (-4.51, 8.59)	4.68
Anan F (2005)	27.00 (14.22, 39.78)	3.51
Anan F (2005)	24.00 (12.53, 35.47)	3.75
Anan F (2005)	35.00 (26.57, 43.43)	4.34
Agabiti-Rosei E (2005)	13.70 (7.19, 20.21)	4.69
Agabiti-Rosei E (2005)	13.30 (6.21, 20.39)	4.58
Grandi AM (2008)		3.07
Caglar N (2011)		4.26
Subtotal (I-squared = 88.9% , $P = 0.000$)	31.90 (22.29, 41.51) 14.93 (10.83, 19.04)	4.11
G3: Age ≥ 60 years old		
Rinder MR (2004)	16.80 (-5.62, 39.22)	6.05
Hinder MR (2004)	16.10 (-6.41, 39.81)	5.78
Iakami I (2011)	◆ 6.60 (4.85, 8.35)	23.81
Iakami I (2011) Fogari P (2012)	3.00 (1.30, 4.70)	23.83
Fogari B (2012)		20.00 19.65
Subtotal (I-squared = 93.5%, <i>P</i> = 0.000)	12.35 (5.98, 18.72)	100.00
NOTE: Weights are from random effects analysis		
	1	
-65 0	65	

FIGURE 7. LVH regression in different age subgroups of overweight and obese hypertensive patients. CI = confidence interval, LVH = left ventricular hypertrophy, WMD = weighted mean difference.

(RAS) is commonly observed in patients with obesity and the levels of angiotensin II (Ang II) and aldosterone are increased in obese patients,^{54–56} so RASI may partly reverse LVH through decreasing the improper activation of RAS. Furthermore, RASI may improve LVH by inhibiting the obesity-induced insulin resistance, because RASI can improve the insulin sensitivity in obese patients.^{57,58} As for other antihypertensive drugs,

although we found they also had an effect on LVH regression, there is still a lack of sufficient evidence to suggest that they have an affirmative effect for LVH regression in overweight and obese hypertensive patients. More studies are needed to explore this issue.

In addition, we found in this study that in overweight and obese hypertensive patients, the 24-h ABPM group had a greater

TABLE 3.	The Reduction	of SBP	and DBP	in	Different	Age
Subaroup	s of Overweight	and Ol	bese Hype	erter	nsive Patie	ents

	SBP, mmHg	DBP, mmHg
G1	19.97 (14.80–21.14)	9.54 (4.02–15.06)
G2 G3	$\begin{array}{c} 14.62 (17.35 - 21.90) \\ 22.12 (19.78 - 24.46) \end{array}$	9.85 (5.87–13.82) 13.68 (11.88–15.47)

G1, 40–49 years' old; G2, 50–59 years' old, and G3, age \geq 60 years. DBP = diastolic blood pressure, SBP = systolic blood pressure.

LVH regression. There are several BP measurement methods such as office or clinic BP measurement and 24-h ABPM. Previous studies have shown that ABPM had a stronger relationship with morbid or fatal events than office BP measurement and was a more sensitive risk predictor of clinical cardiovascular outcomes than office BP.^{10,59,60} Our study further demonstrated that in overweight and obese hypertensive patients, ABPM was also associated with the target organs' damage, for example LVH. Because of the limitation of the data on the publications, we only analyzed this at baseline. However, 24-h ABPM may provide a more reliable measurement for actual BP burden in overweight and obese hypertensive patients. Furthermore, we found significant regression of LVH in different age subgroups, implying that even in older overweight and obese hypertensive patients, as long as the strategy is appropriate, LVH can also be regressed. However, at the same time, we found that the older age (≥ 60 years) influenced the degree of LVH regression in overweight and obese hypertensive patients after adjustment for SBP and DBP reduction. The possible explanation may be because the arterial stiffness is more severe in overweight and obese elderly patients.⁶¹ However, there are other studies showing that obesity is associated with LVH independent of age.⁴⁹ And when compare the influence of age, the effects of antihypertensive therapies cannot be overlooked. So more studies are needed to clarify this issue.

TABLE 4. Determinants of the Statistical Heterogeneity in Multivariable Metaregression Analysis

Variable	Partial Regression Coefficient	Р
Age, y	1.25	0.22
Follow-up time, min	0.78	0.44
Sample size	0.51	0.62
Study quality	-1.11	0.27
BP measurement methods [#]	-2.50	0.017
SBP at baseline, mmHg	-1.97	0.056
DBP at baseline, mmHg	1.35	0.19
LVMI at baseline, g/m^2	3.72	0.001
Type of drugs [*]	-0.68	0.50

BP = blood pressure, DBP = diastolic blood pressure, LVMI = left ventricular mass index, SBP = systolic blood pressure.

* Classified based on the drugs used in study (angiotensin-converting enzyme inhibitors [ACEI], angiotensin receptor blockers [ARB], calcium channel blockers [CCB], beta-receptor blockers, diuretics, and others).

[#] BP measurement methods including 24-h ambulatory BP monitoring (ABPM) method and office/clinic BP measurement method. Begg's funnel plot with pseudo 95% confidence limits



FIGURE 8. Begg funnel plot for publication bias. WMD = weighted mean difference.

Study Limitations

Some limitations of our meta-analysis may restrict the interpretation of results. First, the characteristics among included studies are different, such as the ratio of gender, follow-up time, and drugs used. Inconsistency of these factors may influence the results to some degree. To explore the influence of the above factors, better designed RCTs are required. Second, there are insufficient data on race, dietary salt intake, and pulse wave for a reliable stratified analysis in this study. Third, we only enrolled the studies that evaluated LVH by echocardiography and LVMI was calculated as LVM in grams divided by body surface area in square meters. Whether data from studies evaluating LVH by magnetic resonance imaging and electrocardiogram or by echocardiography but LVMI normalized by height^{2.7} will show similar findings to our results needs further exploring. Fourth, our study is a 'posthoc' categorization of the studies; other analyzed ways, such as those according to prespecified inclusion criteria, should be used in future studies.

In summary, we found that overweight and obesity were associated with LVH independent of BP. RASI was the most effective antihypertensive drug for regressing LVH in overweight and obese hypertensive patients. Monitoring 24-h ABPM may effectively help to evaluate the LVH in overweight and obese hypertensive patients. Antihypertensive treatment at early age could make the overweight and obese hypertensive patients benefit more for LVH regression.

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