THE RELATIONSHIPS BETWEEN BODY MASS INDEX AND LEFT VENTRICULAR DIASTOLIC FUNCTION IN A STRUCTURALLY NORMAL HEART WITH NORMAL EJECTION FRACTION

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BACKGROUND: We conducted research to determine the effect of the weight on left ventricular (LV) diastolic function in Asians, who are at greater risk of cardiovascular events compared to individuals from Western countries with similar body mass indices (BMIs).

METHODS: We studied 543 participants with structurally normal hearts and normal ejection fractions. Participants were classified as normal-weight (BMI < 23.0 kg/m²), overweight (BMI 23.0–27.4 kg/m²), or obese (BMI ≥ 27.5 kg/m²). Peak E velocity, peak A velocity, and E’ velocity were measured and E/E’ was calculated.

RESULTS: Overweight participants had lower E than normal-weight participants (p = 0.001). E’ velocities in overweight and obese participants were less than those in normal weight participants (both p < 0.001). The E/E’ ratio in obese participants was higher compared to the value in normal-weight participants (p < 0.001) and overweight participants (p = 0.025). BMI was associated with E (R = -0.108), A (R = 0.123), E’ (R = -0.229), and E/E’ ratio (R = 0.138) (all p < 0.05). In multivariate analyses, BMI was independently associated with higher A, lower E’, and higher E/E’. The risk of diastolic dysfunction was significantly higher among overweight (adjusted odds ratio: 2.088; 95% confidence interval (CI): 1.348–3.235; p = 0.001) and obese participants (adjusted odds ratio: 5.910; 95% CI: 2.871–12.162; p < 0.001) compared to normal-weight participants.

CONCLUSION: Obesity and overweight independently predicted diastolic dysfunction. An optimal body weight lower than the universal cut-off is reasonable for preventing LV heart failure in Asians.

KEY WORDS: Body weight · Obese · Diastole · Body mass index · Asian.

INTRODUCTION

Obesity and overweight are major determinants of left ventricular (LV) diastolic function. Several mechanisms may contribute to the pathogenesis of LV dysfunction in obese patients. In the obese, cardiac preload and afterload are increased, leading to elevated levels of peripheral resistance. Increased pro-inflammatory cytokines originating from adipose tissue are suggested to be especially important contributors. Furthermore, recent experimental investigations have found that lipo-toxicity in the heart results in cardiac steatosis and lipoapoptosis. In obesity, diastolic function is correlated with fat mass, serum leptin levels, waist-to-hip ratio, LV mass, and LV end-diastolic volume. Increased body mass index (BMI) has also been associated with worse LV diastolic function. However, it is uncertain whether similar relationships exist in Asian populations, because Asians generally have a lower BMI and a higher percentage of body fat at a given BMI compared to individuals from Western countries. Furthermore, Asians have a higher risk of cardiovascular events than individuals in Western populations at a similar BMI. Thus, the World Health Organization (WHO) expert consultation has proposed a new definition for obesity with a focus on the Asia-Pacific region.
WHO criteria. The purpose of this study was to identify the effect of weight on the diastolic function of LV in Asians according to BMI criteria for Asian populations.

METHODS

STUDY POPULATION

We enrolled 543 participants who visited the health promotion center of a tertiary hospital in Busan, South Korea, for health screening from March to December 2012 and performed transthoracic echocardiography. All patients had a medical record filled, including height, weight, heart rate, and blood pressure. We excluded participants with significant valvular heart disease, confirmed regional wall motion abnormalities, decreased LV ejection fraction (< 50%), atrial fibrillation, or congenital heart disease. Demographic data were obtained through a detailed medical history and physical examination. Hypertension was defined as systolic blood pressure of 140 mm Hg or higher, diastolic blood pressure of 90 mm Hg or higher or past history of hypertension. When there is more than 126 mg/dL of fasting plasma glucose or past history of diabetes mellitus, it was defined as diabetes mellitus. Dyslipidemia was defined as having total serum cholesterol level of 240 mg/dL or higher or past history of dyslipidemia. BMI was calculated as weight (kg) divided by height-squared (m²). The study participants were divided into three weight groups according to the criteria suggested by the WHO expert consultation: normal weight (BMI < 23.0 kg/m²), overweight (BMI 23.0–27.4 kg/m²), and obese (BMI ≥ 27.5 kg/m²). The study conformed to the principles of the Declaration of Helsinki and was approved by our Institutional Review Board. The need to obtain written informed consent was waived by the Institutional Review Board.

ECHOCARDIOGRAPHIC ANALYSIS

Transthoracic echocardiography was performed using commercially available systems (iE33, Philips, Andover, MA, USA; Vivid 7, GE, Horten, Norway) by trained sonographers. LV diameter was measured in the parasternal short-axis view as recommended by the American Society of Echocardiography.

LV diastolic function was evaluated using mitral inflow velocity and mitral annular velocity. Peak E and A velocity of the mitral inflow were measured from an apical 4 chamber view, and then E/A ratio was calculated. The mean value of E’ velocities measured by tissue Doppler imaging from septal and lateral walls were used to calculate E/A ratio.

Table 1. Clinical characteristics of populations

|                   | Normal weight (BMI < 23 kg/m²) | Overweight (BMI 23–27.4 kg/m²) | Obese (BMI ≥ 27.5 kg/m²) |
|-------------------|--------------------------------|-------------------------------|--------------------------|
|                   | (n = 208)                      | (n = 271)                     | (n = 64)                 |
| Age, years        | 49.7 ± 9.8                     | 52.0 ± 8.9*                  | 47.5 ± 8.9†              |
| Female, n (%)     | 104 (50.0)                     | 68 (25.1)*                   | 17 (26.6)*               |
| BMI, kg/m²        | 21.0 ± 1.5                     | 24.9 ± 1.2*                  | 29.4 ± 1.6*              |
| Systolic BP, mm Hg| 119.5 ± 17.2                   | 125.9 ± 16.3*                | 132.6 ± 19.2*            |
| Diastolic BP, mm Hg| 70.8 ± 11.2                    | 75.4 ± 10.9*                 | 79.6 ± 13.1*             |
| Heart rate, /min  | 69.0 ± 12.4                    | 66.5 ± 12.4                  | 70.0 ± 10.8              |
| Hypertension, n (%)| 23 (11.1)                      | 76 (28.1)*                   | 22 (34.4)*               |
| Diabetes mellitus, n (%) | 14 (6.7)                 | 18 (6.6)                      | 4 (6.3)                   |
| Dyslipidemia, n (%)| 28 (13.5)                      | 53 (19.6)                     | 18 (28.1)*               |

*p < 0.05 versus normal weight, †p < 0.05 versus overweight. BMI: body mass index, BP: blood pressure

Table 2. LV geometry and systolic function assessed by echocardiography

|                   | Normal weight (BMI < 23 kg/m²) | Overweight (BMI 23–27.4 kg/m²) | Obese (BMI ≥ 27.5 kg/m²) |
|-------------------|--------------------------------|-------------------------------|--------------------------|
|                   | (n = 208)                      | (n = 271)                     | (n = 64)                 |
| LV mass, g        | 127.8 ± 30.4                   | 151.0 ± 28.0*                 | 162.9 ± 29.5*            |
| LV mass/height², g/m²⁷ | 33.1 ± 7.3              | 37.2 ± 6.9*                   | 40.3 ± 8.1*              |
| LV mass/BSA, g/m²  | 78.9 ± 16.6                    | 83.2 ± 14.1*                  | 82.9 ± 14.9              |
| LV end-diastolic dimension, mm | 47.9 ± 3.8               | 50.2 ± 3.5*                   | 51.2 ± 3.0*              |
| LV end-diastolic volume, mL | 83.2 ± 21.0              | 93.5 ± 24.5*                  | 95.1 ± 24.9*             |
| LV end-systolic volume, mL | 30.1 ± 9.1             | 33.8 ± 10.1*                  | 35.4 ± 11.6*             |
| LV ejection fraction, % | 64.0 ± 3.9                | 63.9 ± 4.4                    | 63.3 ± 5.0               |

*p < 0.05 versus normal weight, †p < 0.05 versus overweight. BMI: body mass index, LV: left ventricle, BSA: body surface area
eral annulus was calculated and E/E’ ratio was used as an indicator of LV filling pressure. Definition of diastolic dysfunction was as follows:

- E/A < 0.8: impaired relaxation (grade I)
- 0.8 ≤ E/A ≤ 1.5, E’ < 8 cm/s, and 9 ≤ mean E/E’ ≤ 12: pseudo-normalized pattern (grade II)
- E/A > 2, E’ < 8 cm/s, and mean E/E’ ≥ 13: restrictive pattern (grade III)

Elevated LV filling pressure was defined as when E/E’ ratio exceeded 15.11

**Statistical analysis**

Continuous variables and categorical variables were expressed as mean ± SD and proportions, respectively. One-way analysis and Bonferroni correction were used to assess differences between groups and analyze post hoc multiple comparisons. Fisher’s exact test was used to assess the difference of categorical variables. Independent association between BMI and parameters of diastolic function was evaluated with multiple linear regression. We used multiple logistic model to assess the risk of the LV diastolic dysfunction related to the indicator of body size. SPSS software version 17.0 (SPSS Inc., Chicago, IL, USA) was used and two tailed \( p < 0.05 \) was considered as statistically significant.

**Results**

**Study population and LV mass**

The normal weight, overweight, and obese groups consisted of 208, 271, and 64 participants, respectively. The clinical characteristics and echocardiographic features of the three groups are shown in Tables 1 and 2. Overweight participants were older than normal weight and obese participants. The proportion of women was lower and the proportion of hypertension was higher in the overweight and obese groups. The proportion of patients with dyslipidemia was higher in the obese group than in the normal weight group and overweight group. Obese and overweight participants had higher height-indexed LV mass and BSA-indexed LV mass.

Age and higher BMI were moderately associated with higher height-indexed LV mass (\( R = 0.555, p < 0.001 \) and \( R = 0.371, p < 0.001 \), respectively). The multivariate analysis indicated that a higher BMI may independently predict increased height-indexed LV mass (\( \beta = 0.375, p < 0.001 \)). Age (\( \beta = 0.343, p < 0.001 \)) and heart rate (\( \beta = -0.180, p < 0.001 \)) were also independent predictors. Hypertension and diabetes were not predictors of increased LV mass in multivariate analysis. Similar relationship were shown between BMI and BSA-indexed LV mass (\( \beta = 0.151, p < 0.001 \)).

**BMI and diastolic function parameters**

Higher BMI was associated with higher peak A wave velocity (\( R = 0.123; p = 0.004 \)), higher E/E’ ratio (\( R = 0.138; p = 0.001 \)), lower peak E wave velocity (\( R = -0.108; p = 0.012 \)), and lower

| Table 3. Multivariate analysis for correlation of BMI and other clinical variables with parameters of LV diastolic function |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                  | Peak E E/A ratio | Peak A E/A ratio | Peak E E/E’ ratio | Peak A E/E’ ratio |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| BMI                             | -0.528 (0.046)  | -0.330 (0.001)  | -0.019 (0.005)  | -0.151 < 0.001  | -0.019 (0.027)  | -0.184 < 0.001  | -0.145 (0.072)  | -0.280 < 0.001  |
| Age                             | 0.689 (0.058)   | 0.446 (0.001)   | 0.022 (0.011)   | -0.551 < 0.001  | -0.350 (0.008)  | -0.598 < 0.001  | -0.550 (0.157)  | 0.272 < 0.001   |
| Female                          | -0.006 (0.002)  | -0.118 (0.003)  | 0.000 (0.001)   | 0.200 < 0.001   | -0.013 (0.011)  | -0.136 < 0.001  | -0.013 (0.005)  | 0.272 < 0.001   |
| LV mass index                   | 0.069 (0.026)   | 0.089 (0.008)   | 0.035 (0.040)   | 0.064 (0.070)   | 0.026           | 0.081 (0.094)   | 0.012 (0.040)   | 0.272 < 0.001   |
| Heart rate                      | -0.232 (0.046)  | -0.191 (0.001)  | -0.008 (0.001)  | -0.275 < 0.001  | 0.006           | 0.097 (0.009)   | 0.012 (0.040)   | -0.272 (0.292)  |
| Hypertension                    | -0.351 (1.531)  | 0.102 (0.008)   | -0.187 (0.042)  | 0.159 < 0.001   | -0.008 (0.001)  | 0.022 (0.001)   | -0.008 (0.001)  | 0.102 (0.008)   |
| Diabetes                        | -0.585 (0.030)  | 0.087           | 0.593 (0.015)   | 0.272 < 0.001   | -0.015 (0.005)  | -0.110 < 0.001  | -0.015 (0.005)  | 0.272 < 0.001   |
| BMI body mass index              | 0.961 (0.030)   | 0.087           | 0.971 (0.025)   | 0.173 < 0.001   | -0.027 (0.292)  | -0.097 < 0.002  | -0.027 (0.292)  | 0.173 < 0.001   |
| BMI, body mass index, LV mass index, LV mass index, peak A wave velocity, E wave velocity, E‘ wave velocity, E/A ratio, E/E’ ratio, age, sex, gender, LV mass
Table 4. Multivariate analysis for association between BMI and parameters of LV diastolic function in subgroups with and without risk factors

|       | Peak A | Peak E | Peak A' | E/A ratio | Peak E' | E/E' ratio | B (SE) | p-value | B (SE) | p-value | B (SE) | p-value | B (SE) | p-value |
|-------|--------|--------|---------|-----------|---------|------------|--------|---------|--------|---------|--------|---------|--------|---------|
| Male  |        |        |         |           |         |            |        |         |        |         |        |         |        |         |
| BMI   | 0.764 (0.238) | 0.001 | 0.614 (0.077) | 0.001 | -0.022 (0.002) | < 0.001 | -0.173 (0.002) | < 0.001 | -0.316 (0.002) | < 0.001 |
| Age   | -0.462 (0.073) | < 0.001 | -0.296 (0.002) | < 0.001 | 0.06 (0.002) | < 0.001 | -0.16 (0.002) | < 0.001 | -0.025 (0.002) | < 0.001 |
| Hypertension | 4.115 (1.978) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.12 (0.002) | < 0.001 | -0.18 (0.002) | < 0.001 |
| Diabetes | 0.052 (0.009) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.1 (0.002) | < 0.001 | -0.16 (0.002) | < 0.001 |
| Female |        |        |         |           |         |            |        |         |        |         |        |         |        |         |
| BMI   | -0.56 (0.08) | < 0.001 | -0.31 (0.001) | < 0.001 | -0.027 (0.001) | < 0.001 | -0.15 (0.001) | < 0.001 | -0.12 (0.001) | < 0.001 |
| Age   | -0.60 (0.105) | < 0.001 | -0.36 (0.001) | < 0.001 | 0.05 (0.001) | < 0.001 | -0.21 (0.001) | < 0.001 | -0.09 (0.001) | < 0.001 |
| Hypertension | 6.729 (1.238) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Diabetes | 0.110 (0.034) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Without hypertension |        |        |         |           |         |            |        |         |        |         |        |         |        |         |
| BMI   | 0.381 (0.081) | < 0.001 | 0.18 (0.001) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Age   | -0.59 (0.069) | < 0.001 | -0.34 (0.001) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Hypertension | 6.729 (1.238) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Diabetes | 0.110 (0.034) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| With hypertension |        |        |         |           |         |            |        |         |        |         |        |         |        |         |
| BMI   | 0.125 (0.021) | < 0.001 | -0.006 (0.001) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Age   | -0.71 (0.130) | < 0.001 | -0.35 (0.001) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Hypertension | 6.729 (1.238) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Diabetes | 0.110 (0.034) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Without LV hypertrophy |        |        |         |           |         |            |        |         |        |         |        |         |        |         |
| BMI   | 0.86 (0.187) | < 0.001 | 0.28 (0.001) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Age   | 0.96 (0.196) | < 0.001 | 0.33 (0.001) | < 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Hypertension | 6.729 (1.238) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Diabetes | 0.110 (0.034) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| With LV hypertrophy |        |        |         |           |         |            |        |         |        |         |        |         |        |         |
| BMI   | 0.001 | 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Age   | 0.001 | 0.001 | 0.001 | 0.001 | -0.021 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 | -0.14 (0.002) | < 0.001 |
| Hypertension | 6.729 (1.238) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |
| Diabetes | 0.110 (0.034) | < 0.001 | 0.001 | 0.001 | -0.014 (0.002) | < 0.001 | -0.07 (0.002) | < 0.001 | -0.03 (0.002) | < 0.001 |

BMI: body mass index, LV: left ventricle, E: early transmitral velocity, A: late transmitral velocity, E': early diastolic mitral annulus velocity.
E’ velocity (\(R = -0.229; p < 0.001\)).

Table 3 shows the correlations of BMI and other clinical variables with parameters of LV diastolic function in multivariate analysis. BMI had positive association with peak A velocity (\(R^2 = 0.032; p < 0.001\)) and E/E’ ratio (\(R^2 = 0.026; p < 0.001\)). In contrast, BMI was negatively associated with E/A ratio (\(R^2 = 0.023; p < 0.001\)) and E’ velocity (\(R^2 = 0.034; p < 0.001\)). BMI was not correlated with E wave velocity after multivariate analysis.

Age, gender, and heart rate were independently associated with all LV diastolic parameters (E, A, E/A ratio, E’ and E/E’ ratio). There were significant correlations between higher LV mass index and lower E/A ratio, lower E’ velocity, and higher E/E’ ratio. After dividing the study group according to gender, the results were similar for just men and the entire population (Table 4). However, in women, BMI was associated with E/E’ ratio only.

In subgroup analysis of participants without hypertension (n = 422), BMI was still associated with peak A, E/A ratio, E’ velocity, and E/E’ ratio (Table 4). However, the correlation between BMI and E/E’ ratio was not significant in this subgroup. In the subgroup with LV hypertrophy, BMI was not correlated with any parameters of LV diastolic function. There were significant correlations between BMI and the parameters of LV diastolic function in the non-LV hypertrophy subgroup (Table 4).

**LV DIASTOLIC FUNCTION IN ABNORMAL BODY WEIGHT**

E velocity was significantly lower in overweight participants than in normal-weight participants (\(p = 0.001\)). Peak A velocity was not different between the three groups. The E/A ratio was significantly lower in the overweight and obese groups compared to the normal-weight group (\(p < 0.001\) and \(p = 0.026\), respectively). E’ wave was significantly lower in the overweight and obese groups than in the normal-weight group (both \(p < 0.001\)). The E/E’ ratio was significantly higher in obese participants only compared with normal-weight participants (\(p = 0.001\)) (Table 5).

Among all participants, the prevalence of LV diastolic dysfunction was 54% (n = 293). Diastolic dysfunction was more common in the overweight (60.9%) and obese (65.6%) groups than in the normal-weight group (41.3%) (\(p < 0.001\)). The prevalence of pseudo-normalized diastolic pattern was 26.4, 35.4, and 43.7% in normal weight, overweight and obese, respectively (\(p = 0.017\)) (Fig. 1).

Risk of LV diastolic dysfunction was assessed using a multivariate logistic model (Table 6). Weight [odds ratio (OR): 2.088; 95% confidence interval (CI): 1.348–3.235; \(p = 0.001\)]

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**Table 5. Comparisons of diastolic parameters between three groups**

|                     | Normal weight (BMI < 23 kg/m²) (n = 208) | Overweight (BMI 23–27.4 kg/m²) (n = 271) | Obese (BMI ≥ 27.5 kg/m²) (n = 64) |
|---------------------|------------------------------------------|------------------------------------------|----------------------------------|
| Peak E, cm/s        | 66.1 ± 15.0                              | 61.0 ± 14.5*                            | 64.1 ± 15.1                     |
| Peak A, cm/s        | 59.8 ± 14.7                              | 62.1 ± 14.4                             | 63.7 ± 13.8                     |
| E/A ratio           | 1.2 ± 0.4                                | 1.0 ± 0.3*                              | 1.0 ± 0.3*                      |
| Peak E’, cm/s       | 10.3 ± 2.4                               | 9.2 ± 2.2*                              | 8.8 ± 2.2*                      |
| E/E’ ratio          | 6.6 ± 1.5                                | 6.9 ± 1.8                               | 7.5 ± 1.9*                      |

*\(p < 0.05\) versus normal weight, †\(p < 0.05\) versus overweight. BMI: body mass index, E: early transmitral velocity, A: late transmitral velocity, E’: early diastolic mitral annulus velocity

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**Fig. 1. Proportion of diastolic dysfunction in each weight group.**
and obese (OR: 5.910; 95% CI: 2.871–12.162; p < 0.001) were independent risk factors of diastolic dysfunction. Numerical BMI was also an independent risk factor of diastolic dysfunction (adj usted: 1.163; 95% CI: 1.077–1.257; p < 0.001).

**DISCUSSION**

We analyzed the relationships between LV diastolic function and overweight and obesity as classified by the WHO expert consultation definition for Asians. Our data suggest that BMI has independent correlation with parameters of LV diastolic function and overweight and obese status according to the WHO expert consultation criteria are independent risk factors for LV diastolic dysfunction in Asians. In our study population, the overweight and obese groups had more impaired diastolic function compared with the normal-weight group, and both of these weight groups were independent predictors of LV diastolic dysfunction. It is notable that there was no significant difference in diastolic parameters between obese and overweight participants. Although gender, hypertension, diabetes, and LV hypertrophy also negatively affect LV diastolic function, the relationship between BMI and LV diastolic function maintained after adjusting for these variables. In subgroup analysis of male participants, participants without LV hypertrophy, and participants without hypertension, a significantly negative association between BMI and LV diastolic function was also detected. We found no such significant relationships in women or participants with LV hypertrophy. However, the numbers of women and participants with LV hypertrophy included in the study were small, so the results of the subgroup analysis of these participants should be considered with caution.

Many studies have demonstrated that overweight and obesity are important risk factors for the development of heart failure. Most studies use the most popular WHO BMI criteria of ≥ 25 kg/m² for overweight and ≥ 30 kg/m² for obesity, which were both calculated based on Western populations. However, Asian populations have a lower mean BMI than Western populations, in addition to a higher percentage of Asian populations, in addition to a higher percentage of obesity, and a greater risk for cardiovascular disease at a given BMI. Many experts agree that population-specific cut-off points for BMI are necessary. The WHO expert consultation group observed that the risk of obesity-related diseases among Asians increases from a BMI of 23 kg/m², and suggested appropriate cut-off values for overweight (≥ 25 kg/m²) and obesity (≥ 27.5 kg/m²) in Asians that are lower than the standard WHO criteria. Although these criteria in Asian populations need further validation, we observed that Asians had impaired diastolic function with a BMI ≥ 23 kg/m². There are several BMI criteria for Asians, but the consensus is that the definition of overweight is a BMI ≥ 23 kg/m². The definition of obesity varies, but all criteria for Asians are lower than the universal WHO criteria.

**Table 6. Risk of diastolic dysfunction associated with overweight and obesity (multivariate analysis)**

| Odds ratio | 95% CI | p-value |
|------------|--------|---------|
| Normal weight | Reference | - | - |
| Overweight | 2.088 | 1.348–3.235 | 0.001 |
| Obese | 5.910 | 2.871–12.162 | < 0.001 |

CI: confidence interval

In conclusion, the results of the present study revealed that LV diastolic dysfunction is present in overweight subjects, and that lower BMI categories are appropriate for evaluating relationships among overweight, obese, and LV diastolic dysfunction in Asian populations. On this basis, lower BMI cut-off points to define overweight and obesity are warranted for daily practice and clinical trials in Asian populations. If we expand our goal to the promotion of policies for reducing the burdens of increasing obesity in Asia, a lower cut-off point may be useful for...
stimulating changes in prevention and intervention strategies.

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