

IMPACT OF DIFFERENT GRADES OF BODY MASS INDEX ON LEFT VENTRICULAR STRUCTURE AND FUNCTION

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Abstract : Overweight and obesity influences left ventricular structure and function. WHO Western Pacific Region in 2000 recommended lower cutoff for overweight (Body Mass Index-BMI ≥ 23.0) and obesity (Body Mass Index-BMI ≥ 25.0) in asians. However, studies considering the new recommendations of Body Mass Index (BMI) are lacking. The present study investigated the impact of different grades of BMI on left ventricular structure and systolic and diastolic function in middle aged Indian men. The study involved 74 men aged 31 to 60 (mean age 45.24 ± 10.9) years who were grouped according to BMI as normal weight (18.5 – 22.9 kg/m², n=19), overweight (23 – 24.9 kg/m², n=17) and obese (≥ 25 kg/m², n=38). Left ventricular structure and function were evaluated by 2-D doppler echocardiography. Compared to normal and overweight, obese had significantly higher left ventricular mass ($P < 0.05$) and left atrial diameter ($P < 0.01$). Left ventricular diastolic function (atrial filling velocity-A) showed a significant decline in obese and even in overweight compared to normal ($P < 0.05$). Left ventricular systolic function showed no significant changes with increase in BMI. Left ventricular diastolic function decreases in all grades of BMI more than 23 kg/m², whereas structural changes are present only in obese (BMI ≥ 25 kg/m²). Hence the revised BMI cut-off for Asians as recommended by WHO need to be considered for assessing cardiovascular risk and mortality among Indian men and more stringent control of body weight especially abdominal obesity is justified in the maintenance of cardiovascular health and functional capacity.

Key words : obese overweight left ventricular structure and function

INTRODUCTION

Overweight and obesity constitute an

important public health problem because of the associated increased risk of hypertension, coronary heart disease, type 2 diabetes,

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stroke, gall bladder disease, certain types of cancer, osteoarthritis, sleep apnea, and other disorders (1). A World Health Organization (WHO) Consultation described obesity as a chronic disease that is so prevalent in both developed and developing countries that it is replacing the more traditional public health concerns, such as undernutrition and infectious diseases, as a significant contributor to ill health (2).

Body Mass Index (BMI) is currently recognized and widely used for identifying overweight or obesity. Internationally recognized cutoff points of BMI for defining overweight is $\text{BMI} \geq 25.0 \text{ kg/m}^2$ and obesity is $\text{BMI} \geq 30.0 \text{ kg/m}^2$. However percentage of body fat is not uniform among regional populations. A report co-sponsored by the WHO Western Pacific Region in 2000 recommended different ranges for classifying overweight and obesity for populations within the Asia-Pacific region. Increase in health-related risk factors and comorbidities associated with obesity occur at a lower BMI in Asian populations than in other ethnic groups. Thus lower cut-off points for Asians were identified for overweight ($\text{BMI} \geq 23.0 \text{ kg/m}^2$) and obesity ($\text{BMI} \geq 25.0 \text{ kg/m}^2$) (3).

Prevalence studies among Chinese using new criteria for overweight and obesity have shown rise in obesity in the last decade (4). Also recent studies have suggested that waist-hip ratio (W/H) is better predictor of cardiovascular risk than BMI (5). Alteration in left ventricular structure and function have been demonstrated in obese but studies considering new WHO recommendation of $\text{BMI} \geq 23$ as overweight and $\text{BMI} \geq 25$ as obese are lacking in Asians (5). This study explored whether according to the new cutoffs overweight and obesity affect the anatomy

and physiology of heart in our population.

MATERIALS AND METHODS

The study included 74 asymptomatic men aged 31 to 60 years. In order to exclude conditions that might influence the results, the following criteria were required: male, in age group of 31–60 years; no previous history or clinical evidence of hypertension, diabetes mellitus, coronary artery disease, heart failure, or cardiac valve disease; normal ECG; no respiratory disease; not suffering from any chronic or acute disease; not taking any drugs that could affect the heart; and not involved in competitive sports. Echocardiographic images had to be of sufficient quality to allow reproducible cross sectional, M mode, and Doppler studies.

All subjects provided fully informed written consent for their participation in the study. The study was approved by the ethical committee of the Medical College, Baroda.

All participants provided information on age, family history, personal habits (alcohol intake, tobacco consumption, type and level of physical exercise, drug ingestion, known pathological conditions). A detailed physical examination was conducted to exclude endocrine and cardiac co-morbidities. Height and weight were measured and the BMI was calculated as the weight (kg)/height² (m²). Waist-Hip (W/H) ratio was calculated from waist and hip circumference in cm. General clinical parameters including pulse rate and Blood Pressure were measured. A 12 lead ECG was obtained.

Overweight and obesity were defined as $\text{BMI} \geq 23$ and $\text{BMI} \geq 25$ respectively (3). The participants in the study were classified into three groups based on the BMI: A-a normal

weight (control) group had a BMI of $< 23 \text{ kg/m}^2$; B-overweight group with BMI between $23\text{--}24.9 \text{ kg/m}^2$; and C-obese with BMI between $25\text{--}29.9 \text{ kg/m}^2$ (obese group was further divided into three groups as C1- $25\text{--}26.9 \text{ kg/m}^2$, C2- $27\text{--}28.9 \text{ kg/m}^2$, C3- $\geq 29 \text{ kg/m}^2$ for intra-group comparison).

A cross sectional echocardiogram was obtained on all participants (Sonos 5500, Hewlett-Packard, equipped with Mediview software, Altech star Solutions Pvt. Ltd.). Echocardiograms included cross sectional, M mode, and Doppler studies. Triplicate measurements of all variables were made off-line by one observer who was blinded to the patients' clinical details.

The following indices of cardiac function were evaluated (6):

Left ventricular systolic function— Left ventricular end diastolic (EDD) and end systolic diameter (ESD) and fractional shortening (FS) were obtained in the parasternal long axis views using M mode; left ventricular end diastolic (EDV) and end systolic volumes (ESV), stroke volume (SV) and ejection fraction (EF) were measured from apical four chamber view using the monoplane area-length method. Cardiac output (CO) was obtained by multiplying stroke volume with heart rate. All the above parameters were adjusted for size by dividing with body surface area. The relative wall thickness (RWT) was calculated from the posterior wall thickness (PWT) and the EDD, as $(2 \times \text{PWT})/\text{EDD}$. Left ventricular mass (LVM) was calculated by the formula introduced by Devereux et al. $\text{LV mass} = 0.8[1.4(\text{IVSTd} + \text{LVIDd} + \text{PWTd})^3 - (\text{LVIDd})^3] + 0.6 \text{g}$. Height based adjustment was done by dividing LVM by height^{2.7}.

Left ventricular diastolic function— Pulsed Doppler measurements were obtained in the apical four chamber view: the Doppler beam was aligned as perpendicularly as possible to the plane of the mitral annulus and a 5 mm pulsed wave Doppler sample volume was placed between the tips of the mitral leaflets during diastole. The following variables were calculated: maximum velocity of passive mitral filling (E); maximum velocity of active mitral filling (A); ratio of passive to active velocity (E/A). The left atrial diameter was measured using M mode in the parasternal long axis view.

The data was analyzed as per BMI groups as well as by dividing the subjects in three groups according to Waist-Hip ratio (W/H ratio < 0.9 , W/H ratio $= 0.9\text{--}1$, W/H ratio > 1). Mean and standard deviation were calculated. One-Way ANOVA with post-hoc Tukey's HSD test was applied to compare the study groups. Pearson's correlation coefficient (r) was obtained to study the correlation of BMI and Waist-Hip ratio with other variables. Probability value P of less than 0.05 was considered statistically significant.

RESULTS

Weight and BMI were significantly different within the obese subgroups and also with respect to the normal and overweight groups. Waist circumference, hip circumference and waist-hip ratio increases linearly with increase in BMI. Systolic blood pressure was significantly higher in the obese group compared to the overweight (Table I).

Left atrial and ventricular structural parameters are shown in Table II. Compared to normal, the left atrial diameter (LAD) and left ventricular mass were significantly

TABLE I: General characteristics of the study group (All values are mean±SD).

	A (Normal) (n=19)	B (Overweight) (n=17)	C1 (Obese) (n=15)	C2 (Obese) (n=11)	C3 (Obese) (n=12)	F	df	P
Age (years)	42.66±13.74	45±11.96	46.47±11.18	46.14±13.2	45±5.72	0.104	4	0.98
Height (cm)	169.9±6.9	165.7±5.87	167.8±6.89	168.4±8.6	166.7±5.7	0.544	4	0.70
Weight (kg)	62.66±5.91	66.64±5.86	73.26±6.47 ^{^*}	79.57±8.42 ^{^*}	90.16±12 ^{^*}	21.99	4	0.00
BMI (kg/m ²)	21.68±1.17	24.21±0.7 [*]	25.96±0.57 ^{^*}	27.98±0.72 ^{^*}	32.3±3.34 ^{^*}	65.51	4	0.00
WC (cm)	80.22±5.6	87.89±5.3 [*]	91.07±5.21 [*]	96.42±2.6 ^{^*}	107.25±5.6 ^{^*}	42.38	4	0.00
HC(cm)	90.11±3.9	96.32±4.9 [*]	98.26±4.26 [*]	103±4.04 [*]	110.66±7.98 [*]	24.50	4	0.00
Waist/Hip ratio	0.89±0.04	0.91±0.04	0.92±0.04 [*]	0.93±0.03 [*]	0.97±0.06 ^{^*}	4.85	4	0.00
Pulse (beats/min)	78.55±17.55	79.42±12.2	81.78±19.9	75.42±7.8	80.58±11.4	0.285	4	0.88
SBP (mmHg)	126.66±18.7	121.42±9.49	132.6±14.0	134.2±7.8 [^]	130.8±7.9	2.4	4	0.04
DBP (mmHg)	80±8.66	81.42±5.34	84.21±7.68	85.42±4.5	84.66±6.5	1.22	4	0.31

*P<0.05 comparing with normal weight. [^]P<0.05 comparing with overweight.

BMI-body mass index, SBP-systolic blood pressure, DBP- diastolic blood pressure, HC-Hip circumference, WC-waist circumference.

TABLE II: Left atrial and ventricular structural parameters (All values are mean±SD).

	A (Normal) (n=19)	B (Overweight) (n=17)	C1 (Obese) (n=15)	C2 (Obese) (n=11)	C3 (Obese) (n=12)	F	df	P
LAD (cm)	3.05±0.28	3.13±1.14	3.32±0.33 ^{^*}	3.63±0.42 ^{^*}	3.36±0.26 ^{^*}	3.463	4	0.01
LVM (g)	144.06±51.06	157.03±40.68	193.83±54.47 [*]	182.85±50.99	174.04±40.07	2.336	4	0.04
LVM/Ht ^{2.7}	35.35±15.08	40.5±11.44	47.17±11.04	44.1±14.2	45±11.36	1.86	4	0.13
PWTd (cm)	0.95±0.27	1.02±0.18	1.14±0.19	1.09±0.24	1.04±0.12	1.24	4	0.37
PWTs (cm)	1.41±0.21	1.35±0.19	1.47±0.19	1.48±0.22	1.44±0.27	0.604	4	0.66
IVSTd (cm)	1.0±0.16	1.04±0.16	1.2±0.22	1.1±0.2	1.13±0.15	1.918	4	0.12
IVSTs (cm)	1.4±0.21	1.36±0.19	1.53±0.26	1.46±0.16	1.56±0.1	1.602	4	0.19
RWT	0.45±0.11	0.47±0.08	0.53±0.09	0.48±0.11	0.48±0.04	0.88	4	0.52

*P<0.05 comparing with normal weight. [^]P<0.05 comparing with overweight.

LAD-left atrial diameter, LVM-left ventricular mass, LVM/Ht^{2.7}-left ventricular mass adjusted for height, PWTs-posterior wall thickness in systole, PWTd-posterior wall thickness in diastole, IVSTs-inter ventricular septal thickness in systole, IVSTd-inter ventricular septal thickness in diastole, RWT-relative wall thickness.

higher in the obese group. Left ventricular mass adjusted for height (LVM/Ht^{2.7}), interventricular septal thickness in systole and diastole as well as posterior wall thickness in systole and diastole were higher

in obese but not statistically significant.

As shown in Table III left ventricular systolic function showed no significant change with increase in BMI. Significant

TABLE III: Left ventricular systolic and diastolic function (All values are mean±SD).

	A (Normal) (n=19)	B (Overweight) (n=17)	C1 (Obese) (n=15)	C2 (Obese) (n=11)	C3 (Obese) (n=12)	F	df	P
EF (%)	59.25±1.83	59.14±4.81	59.26±4.87	58.83±4.91	58±4.28	0.154	4	0.96
FS (%)	32.06±3.7	31.53±3.84	30.89±2.66	31.13±2.55	30.18±3.15	0.357	4	0.83
SVI (ml/m ²)	36±11.13	36.7±9.19	39.4±8.07	38.58±9.3	35.2±8.75	0.197	4	0.93
CI (L/min/m ²)	2.77±0.91	2.91±0.87	2.9±0.05	2.89±0.7	2.8±0.68	0.288	4	0.88
ESVI (ml/m ²)	14.02±6.59	13.16±3.56	13.56±3.56	14.88±8.74	13.9±4.6	0.413	4	0.79
EDVI (ml/m ²)	50.03±15.52	49.88±10.52	50.01±9.76	53.46±13.64	49.1±10.52	0.285	4	0.88
E (cm/sec)	0.88±0.18	0.89±0.17	0.83±0.21	0.75±0.22	0.85±0.16	0.568	4	0.68
A (cm/sec)	0.63±0.17	0.79±0.22 [*]	0.73±0.21 [*]	0.73±0.11 [*]	0.71±0.16 [*]	2.74	4	0.04
E/A	1.59±0.96	1.22±0.48	1.26±0.58	1.26±0.38	1.25±0.37	0.113	4	0.97

*P<0.05 comparing with normal weight.

EDD-end diastolic diameter of left ventricular, EDVI-end diastolic volume index, ESD-end systolic diameter, ESVI-end systolic volume index, EF-ejection fraction, FS-fractional shortening, SVI-stroke volume index, CI-cardiac index, E-early or passive mitral filling velocity, A-atrial or active mitral filling velocity, E/A-ratio of early to atrial mitral filling velocities.

decrease in diastolic function in form of increased atrial filling velocity (A) demonstrated in obese and even in the overweight compared to normal. A similar decrease in ratio of early to atrial filling velocities (E/A) was seen in obese and overweight but not statistically significant.

Table IV exhibits correlation of BMI and Waist-Hip ratio with other parameters. Waist and hip circumference and waist-hip ratio had a significant positive correlation with BMI. Diastolic blood pressure also showed a significant positive correlation whereas other parameters were not linearly associated with increase in BMI. Apart from weight and BMI, waist-hip ratio shows a strong linear correlation with left atrial diameter.

On dividing the study group according to waist-hip ratio (Table V), anthropometric variables like height, weight, BMI and waist

TABLE IV: Correlation of BMI and Waist-Hip ratio with other variables.

	Pearson correlation co-efficient (r)	
	BMI	W/H ratio
BMI (kg/m ²)	1	0.369**
Age (years)	0.02	0.250
Height (cm)	-0.026	0.023
Weight (kg)	0.873**	0.398**
Waist circumference (cm)	0.867**	0.667**
Hip circumference (cm)	0.865**	0.201
Waist/Hip ratio	0.369**	1
Pulse (beats/min)	0.059	0.249
SBP (mmHg)	0.186	0.197
DBP (mmHg)	0.257*	0.181
LAD (cm)	0.225	0.349*
LVM(g)	0.199	0.206
LVM/Ht ^{2.7} (g/m ^{2.7})	0.217	0.172
RWT	0.077	0.183
EF (%)	-0.095	-0.035
FS (%)	-0.133	-0.062
SVI (ml/m ²)	-0.062	0.009
CI (L/min/m ²)	-0.14	0.11
ESVI (ml/m ²)	0.064	-0.013
EDVI (ml/m ²)	-0.021	0.001
E (cm/sec)	-0.074	-0.159
A (cm/sec)	-0.040	0.096
E/A	-0.75	-0.199

*P value <0.05, **P value <0.01.

TABLE V: Different parameters of Study group divided according to W/H ratio (All values are mean±SD).

	W/H <0.9 (n=26)	W/H= 0.9-1 (n=37)	W/H >1 (n=11)	F	df	P
Age (years)	42.4±12.92	45.83±9.95	50.8±11.85	1.22	2	0.30
Height (cm)	168.93±7.39	166.1±5.75	174.6±5.81 [^]	4.77	2	0.01
Weight (kg)	68.27±8.84	73.86±12.38	89.4±11.82* [^]	6.22	2	0.00
BMI (kg/m ²)	23.9±2.58	26.74±3.96*	29.28±3.07*	4.98	2	0.01
WC (cm)	83.47±8.04	93.55±8.85*	106.4±6.43* [^]	15.36	2	0.00
HC (cm)	97.07±7.14	99.8±9.08	102.4±5.58	0.93	2	0.40
Waist/Hip ratio	0.85±0.03	0.93±0.02*	1.03±0.04* [^]	80.74	2	0.00
Pulse (beats/min)	79.73±17.96	78.71±13.45	86.8±19.47	0.64	2	0.53
SBP (mmHg)	126±13.52	132.67±11.62	142±13.04* [^]	3.73	2	0.03
DBP (mmHg)	81.33±8.34	83.13±6.85	88±8.37	1.83	2	0.16
LAD (cm)	3.08±0.26	3.29±0.32	3.56±0.42*	3.56	2	0.03
LVM(g)	174.03±55.3	168.32±42.02	255.21±84.34* [^]	4.47	2	0.01
LVM/Ht ^{2.7} (g/m ^{2.7})	42.19±14.9	43.7±12.21	55.69±14.42	1.16	2	0.21
PWTd (cm)	1.07±0.24	1.02±0.19	1.36±0.29 [^]	3.52	2	0.03
PWTs (cm)	1.31±0.24	1.45±0.18	1.58±0.25	2.67	2	0.08
IVSTd (cm)	1.16±0.16	1.07±0.17	1.45±0.28 [^]	6.43	2	0.00
IVSTs (cm)	1.4±0.29	1.47±0.19	1.6±0.17	1.03	2	0.36
RWT	0.51±0.09	0.46±0.08	0.62±0.13 [^]	5.33	2	0.00
EF (%)	58±2.25	59.39±4.93	57±1.15	0.95	2	0.39
FS (%)	30.07±2.16	31.62±3.41	28.75±0.95	2.52	2	0.08
SVI (ml/m ²)	32.83±7.91	37.43±8.89	31.64±7.68	2.0	2	0.14
CI (L/min/m ²)	2.56±0.68	2.91±0.74	2.73±0.74	1.19	2	0.31
ESVI (ml/m ²)	12.11±3.36	13.65±5	13.03±2.23	0.60	2	0.55
EDVI (ml/m ²)	44.94±9.67	51.08±11.09	44.68±8.45	2.1	2	0.13
E (cm/sec)	0.84±0.23	0.86±0.17	0.63±0.18	2.54	2	0.08
A (cm/sec)	0.77±0.21	0.71±0.18	0.79±0.12	0.77	2	0.46
E/A	1.16±0.46	1.29±0.45	0.83±0.34	2.11	2	0.13

*P<0.05 comparing with W/H ratio <0.9. [^]P<0.05 comparing with W/H ratio=0.9-1.

circumference significantly increased with increase in W/H ratio. Systolic blood pressure, left atrial diameter, left ventricular mass and left ventricular wall thickness parameters (PWTd, IVSTd and RWT) showed a significant increase with W/H ratio. Other parameters showed no significant change.

DISCUSSION

The BMI cut-off levels for Asians differ from that of Europeans. The WHO expert committee has revised the BMI cut-off for Asian Indians based on increasing evidence of a high prevalence of type 2 diabetes mellitus and cardiovascular disease in Asian countries despite an average BMI < 25 kg/m² in these countries (3). In our study group, increase in BMI is associated with significant linear increase in waist circumference, hip circumference and waist-hip ratio suggesting abdominal obesity might be contributing to the increase in BMI. Hanumanthappa et al (2008) have shown a similar finding of waist circumference and waist-hip ratio contributing to increase in BMI in Indian men (7).

Systolic blood pressure was higher in obese group and those with W/H ratio of >1 and diastolic blood pressure showed a linear increase with increase in BMI. Studies by Karason (1998) and Okosun (1999) have similar findings and increase in blood pressure is associated more with abdominal obesity. Altered circulation with increase in peripheral resistance and volume overload in obese especially abdominal obese contributes to high blood pressure (8–11).

Structural parameters like left ventricular

mass and left atrial diameter showed a significant change in obese as well as in those with W/H ratio of >1 in our study group. Also left atrial diameter showed a strong linear correlation with waist-hip ratio suggesting adiposity especially in abdomen might be contributing to structural changes. Gates et al (2003) showed abdominal obesity contributes to left ventricular remodeling and reduced diastolic function (12). As shown by Krishnan (2005) structural remodeling is seen in overweight and obese. Blood pressure changes as well as increased renin-angiotension-aldosterone and adrenergic system activation in obese might contribute to it (13, 14, 18). Increase in blood pressure contributes to increased left ventricular mass and wall thickness and further this increases the resistance to ventricular filling contributing to increased left atrial pressure and hence structure changes in left atrium.

Study by Pascual et al (2003) have demonstrated a higher systolic function and predicted that systolic function might be affected with severe obesity only. In our study group left ventricular diameters and volumes adjusted for body surface area as well as contractility indices (ejection fraction and fractional shortening) showed no significant change with increase in BMI or W/H ratio probably compensated by structural changes and they might be affected with still higher BMI only (15–18).

Diastolic function showed decline even with mild increase in BMI from normal to overweight (BMI ≥ 23 kg/m²) and the decline was also seen in obese. There was no linear association between BMI or W/H ratio and diastolic function. Alwi et al (2006) and others have demonstrated similar decline in

diastolic function in obese (19–25). The exact mechanism for dysfunction is not well known but cardiac adaptation to chronic volume overload in obese is associated with eccentric hypertrophy and abnormalities of diastolic function from the initial stages (25). As discussed above the increased mass of ventricles contributes to increased resistance to ventricular filling hence contributing to decrease in diastolic function as observed from increased atrial filling velocity.

Structural changes in left atrial diameter

and left ventricle wall in form of increased mass appears with BMI more than 25 kg/m² and continue with further increase in BMI. Left ventricular diastolic function is affected even with mild increase in BMI of 23–24.9 kg/m² whereas systolic function is unaltered in our study group. Hence the revised BMI cut-off for Asians as recommended by WHO need to be considered for assessing cardiovascular risk and mortality among Indian men. More stringent control of body weight especially abdominal obesity is justified in the maintenance of cardiovascular health and functional capacity.

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