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Association of body mass index and diastolic function in metabolically healthy obese with preserved ejection fraction☆

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ABSTRACT

Background: Small scale cohorts demonstrated an association between body mass index (BMI) and diastolic function in a metabolically healthy population. We aimed to characterize the relation between BMI and diastolic function in a relatively large cohort of metabolically healthy obese with preserved ejection fraction.

Methods and results: Echocardiograms of metabolically healthy patients between 2011 and 2016, who had no significant valvulopathies or atrial fibrillation, and had preserved ejection fraction, were retrospectively identified and analyzed. Metabolically healthy was defined as lack of known diabetes mellitus, hypertension, and hyperlipidemia. Patients were categorized into 4 groups according to BMI - normal BMI 18.5-25, overweight 25.01-30, obese 30.01-35, morbidly obese >35 kg/m^2. The cohort consisted of 7057 individuals, 54.9% males, with a mean age 54 years. Patients in higher BMI groups more commonly demonstrated abnormalities in most echocardiographic parameters associated with diastolic dysfunction, including left atrial volume index>34 ml/m^2, E/e′>14, e' lateral<10 cm/s, e' septal<7 cm/s, tricuspid regurgitation velocity>2.8 m/s and systolic pulmonary artery pressure≥36 mmHg (p<0.01 for all comparisons). Morbidly obese carried the highest risk compared to those with normal BMI. There were no significant differences between the groups in rates of readmission due to heart failure.

Conclusion: High BMI is associated with increased risk of diastolic dysfunction even in metabolically healthy patients. Additional trials are needed in order to evaluate whether these echocardiographic findings translate into clinical implications.

1. Introduction

Obesity is associated with several alterations in cardiac structure and function including left ventricular (LV) hypertrophy and diastolic dysfunction [1–11]. The influence on diastolic function and hemodynamics seems to be multifactorial, and may result from effects of adipose tissue [2,4–12], as well as from comorbidities which are associated with obesity, such as diabetes mellitus, dyslipidemia and hypertension [12]. Obese individuals without obesity-related metabolic abnormalities have been referred to as "metabolically healthy obese" [13–18]. Previous studies demonstrated an association between body mass index (BMI) and diastolic dysfunction in a metabolically healthy population [2,3,7,9–11]. However, these studies were limited by their small cohorts and by non-consistent criteria for the definition and diagnosis of diastolic dysfunction. Large scale studies are lacking, and data remain scarce. Current guidelines recommend different criteria of diastolic function assessment for patients with preserved ejection fraction (EF) compared to those with reduced EF [19]. The differentiation was not consistent throughout previous studies. In the present study we aimed to perform a comprehensive diastolic function assessment on a large cohort of metabolically healthy obese with preserved EF.

2. Methods

2.1. Study design and setting

The cohort is a single-center retrospective analysis of patients who underwent echocardiography between 2011 and 2016 in our medical center. In case of multiple echocardiograms only the first examination was regarded. Patients were included if they were over 18 years of age and had BMI data available. All individuals were considered metabolically healthy [18], defined as lack of known diabetes mellitus, hypertension, and hyperlipidemia. Individuals with aortic regurgitation or stenosis (≥moderate), mitral regurgitation or stenosis (≥moderate), or atrial fibrillation were excluded. In addition, patients with EF under 50%, and patients with extreme BMIs (<18.5 or >50) were excluded. The study was reviewed and approved by the Institutional Review Board, with a waiver of informed consent.

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2.2. Variables, data source and measurement

Age, gender, BMI, and major co-morbidities were extracted from the electronic health record (EMR).

2.3. Echocardiography

Echocardiography was performed in a standard manner, using the same equipment (iE33, Philips Medical Systems, Bothell, WA). Left atrial volume was calculated using the biplane area length method at end systole [20]. Left atrial volume measurements were divided by body surface area and reported as indices in milliliter/square meter (ml/m^2). Pulsed-wave (PW) Doppler was performed in apical 4-chamber view in order to obtain mitral inflow velocities for assessment of LV filling. A 1-mm to 3-mm sample volume was placed between the mitral leaflet tips at end-expiration and during diastole after optimizing spectral gain, wall filter settings, and setting sweep speeds of 100 mm/s. Recordings were averaged over 3 consecutive cardiac cycles. Measurements of mitral inflow included peak early filling (E wave) and late diastolic filling (A wave) velocities, E/A ratio, and deceleration time of early filling velocity. Early diastolic mitral annular velocities (e′) were measured in the apical 4-chamber view. The e' was measured from septal and lateral annulus. The ratio of peak E to peak e′ (average) was calculated (mitral E/e′ ratio) from the average of at least 3 cardiac cycles [19]. EF was calculated by the Quinones method, or Simpson's method in patients with segmental wall abnormalities. LV diameters, posterior wall width, and inter-ventricular septal diameter were measured as recommended. Forward stroke volume was calculated from LV outflow tract with subsequent calculation of cardiac output. Hemodynamic assessment estimated right atrial pressure using the inferior vena cava to calculate the systolic pulmonary artery pressure. Right ventricular (RV) function was evaluated by Tricuspid Annular Plane Systolic Excursion (TAPSE) and RV s' [20].

2.4. Statistical methods

Categorical variables were reported as numbers or percentages, and continuous variables were reported as means and standard deviations. Continuous variables were tested for normal distribution using histograms and Q-Q Plots. Patients were divided into groups according to their BMI (normal BMI 18.5–25, overweight 25.01–30, obese 30.01–35, morbidly obese >35 kg/m^2). Continuous variables were compared between groups using Analysis of Variance (ANOVA) or Mann-Whitney test, and categorical variables were compared using Chi-square test or Fisher's exact test. Univariable logistic regressions were used to evaluate the associations between BMI and diastolic function. Age, gender and baseline parameters with a p-value<0.05 were included in the multivariable analyses. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported. Data for co-morbidities were not complete for ambulatory individuals, therefore multivariable analysis is presented only for ambulatory patients. A two tailed p-value <0.05 was considered as statistically significant. All statistical analyses were performed with SPSS (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

3. Results

3.1. Patient characteristics

The cohort consisted of 7,057 individuals, 54.9% males, with a mean age of 54(±19) years. Female gender was more prevalent among morbidly obese and age was inversely related to BMI (Table 1). Ambulatory individuals comprised 48% of the entire cohort (n =3,393), while 52% (n =4367) of the patients were hospitalized during the echocardiographic assessment. Baseline characteristics of hospitalized patients according to BMI category are presented in Table 2.

3.2. Echocardiographic characteristics

High BMI was associated with higher cardiac output and stroke volume, as well as larger LV dimensions, including end systolic and diastolic diameters, and posterior wall width and inter-ventricular septal diameter (p<0.001 for all of the comparisons). There was no significant difference in LV EF between different BMI groups (p=0.75). Left atrial volume index, A wave, E/e' ratio, and systolic pulmonary artery pressure, were higher in patients with higher BMIs compared to those with lower BMIs, while E/A demonstrated an opposite trend ($p < 0.001$ for all of the comparisons). Parameters evaluating RV function – TAPSE and RV s' tended to be higher in patients with higher BMIs ($p = 0.022$ and $p = 0.084$, respectively). A detailed description of echocardiographic parameters is presented in Table 1. Separate analyses for inpatients and outpatients demonstrated similar trends and are presented in Supplemental Table 1.

Table 3 presents a comparison of diastolic assessment according to BMI. Patients in higher BMI groups more commonly demonstrated values of most echocardiographic parameters which are associated with diastolic dysfunction, including left atrial volume index>34 ml/m^2, E/e'>14, e' lateral<10 cm/s, e' septal<7 cm/s, and tricuspid regurgitation velocity > 2.8 m/s (Fig. 1). In contrary, patients with higher BMIs had a

Table 1
Demographic and echocardiographic characteristics according to BMI category.

BMI (kg/m^2)	Normal BMI 18.5–24.9 n=3,355	Overweight 25-29.9 n=2,479	Obese 30-34.9 n=915	Morbidly obese ≥35 n=308	p-Value
Demographic characteristics					
BMI	22.5(±1.7)	27.2(±1.4)	31.9(±1.4)	39.6(±4.7)	
Age	50(±20)	57(±17)	59(±16)	57(±16)	<0.001
Male gender, %	51	62	51	45	<0.001
Echocardiographic characteristics					
Ejection fraction, %	59.3(±2.5)	59.3(±2.6)	59.1(±2.9)	59.1(±2.7)	0.75
Cardiac output, l/min	5.1(±1.3)	5.5(±1.4)	5.7(±1.4)	5.9(±1.5)	<0.001
Stroke volume, ml	72.3(±18.5)	77.7(±19.5)	78.7(±18.2)	79.5(±18.9)	<0.001
Left ventricle end diastolic diameter, mm	46.1(±5.1)	47(±4.9)	47.7(±5.2)	48.4(±5.2)	<0.001
Left ventricle end systolic diameter, mm	28.4(±4.9)	28.7(±4.6)	29.2(±5.3)	29.6(±5.1)	<0.001
Left ventricular posterior wall diameter, mm	7.2(±3)	7.1(±4)	7.3(±4.3)	7.6(±4.4)	<0.001
Interventricular septal diameter, mm	9(±2.1)	10.3(±2.2)	10.9(±2.4)	11.3(±2.2)	<0.001
Left atrial volume index, ml/m^2	29.8(±10.6)	31.6(±11)	32.8(±12)	33(±12.3)	<0.001
Deceleration time, ms	176(±73)	178(±77)	180(±78)	176(±71)	0.574
e' lateral, cm/s	11.5(±4.2)	9.9(±3.4)	9.4(±3.1)	9.5(±3.1)	<0.001
e' septal, cm/s	8.6(±3)	7.4(±2.4)	7.1(±2.1)	7(±2.2)	<0.001
E/e average	7.8(±3.8)	8.3(±3.9)	8.6(±4.2)	8.7(±4.5)	<0.001
A wave, m/s	0.66(±0.25)	0.73(±0.26)	0.78(±0.27)	0.8(±0.26)	<0.001
E wave, m/s	0.77(±0.26)	0.75(±0.23)	0.76(±0.25)	0.8(±0.25)	<0.001
E/A ratio	1.3(±0.6)	1.11(±0.51)	1.04(±0.47)	1.08(±0.53)	<0.001
Systolic pulmonary pressure, mmHg	29(±6.6)	29.6(±6.4)	30.4(±7)	31.3(±7.6)	<0.001
Right atrial pressure, mmHg	5.9(±3.2)	6(±3.4)	6(±3.4)	6.5(±4)	0.212
Right atrial area, cm^2	15.4(±3.8)	16.5(±4)	17(±4.2)	18.7(±7.4)	<0.001
Tricuspid annular plane systolic excursion, mm	20.8(±7.4)	21(±7.7)	21(±8)	22.5(±7.1)	0.022
Right ventricle s', cm/s	11.6(±4.5)	11.5(±4.5)	11.3(±5.1)	12.8(±3.7)	0.084

Table 2
Baseline characteristics of hospitalized patients according to BMI category.

BMI (kg/m²)	Normal BMI 18.5-24.9 n=2,072	Overweight 25-29.9 n=1,536	Obese 30-34.9 n=558	Morbidly obese ≥35 n=201	p-Value
BMI	22.5(±1.7)	28.2(±1.4)	31.9(±1.4)	39.4(±4.4)	
Age	54.5(±20)	58.1(±17.2)	58.3(±16.8)	56(±17)	<0.001
Male gender, %	55.7	66.3	58.2	46.3	<0.001
Ischemic heart disease, %	5	5.9	4.7	2.5	0.177
Pacemaker/Implantable cardioverter defibrillator, %	1.2	1.4	0.9	2	0.649
Cerebrovascular accident/Transient ischemic attack, %	0.6	0.7	1.6	0	0.074
Lung disease, %	6.2	5.4	5.4	5.5	0.717
Deep vein thrombosis/Pulmonary embolism, %	0.5	0.8	0.9	0	0.419
Malignancy, %	7	5.8	5.7	7.5	0.4
Renal dysfunction, %	6	3.6	2.9	4	0.001
Anemia, %	35.6	28.6	28.7	29.4	<0.001
Smoking, %	12.2	11.6	10.9	10	0.715

lower risk for E/A ratio>2 compared to patients with normal BMI. Multivariable analyses demonstrated increased risks for left atrial volume index>34 ml/m² (OR 1.5, 95% CI 1.1–2.2, p = 0.015) and E/e′ > 14 (OR 2.3 95% CI 1.4-3.6, p=0.001) only in morbidly obese, and increased risks for and tricuspid regurgitation velocity>2.8 m/s in obese and morbidly obese. The risk for low e' (septal and lateral) among higher BMI categories remained significant (p<0.05 for all comparisons) in multivariable analyses (Table 3). Separate analyses for inpatients and outpatients are presented in Supplemental Table 2.

3.3. Clinical outcomes

There were no significant differences between the groups in readmission due to heart failure. Rates of readmission due to heart failure among hospitalized patients were 0.9%, 1%, 1.1%, and 2% at 3 years for normal BMI, overweight, obese, and morbidly obese, respectively (p=0.554 for the entire comparison). Rates for readmission due to heart failure for the entire cohort were 0.6%, 0.8%, 0.6%, and 1.5% at 3 years for normal BMI, overweight, obese, and morbidly obese, respectively (p=0.309 for the entire comparison). After adjustment for age and gender ORs for readmission due to heart failure were 1.1 (95% CI 0.61-2, p=0.762) for overweight, 0.78 (95% CI 0.32-1.83, p=0.596) for obese, and 2.01 (95% CI 0.75-5.36, p=0.164) for morbidly obese, compared to normal BMI. Data are not presented in a table.

4. Discussion

The present study is the first to perform a comprehensive echocardiographic assessment of diastolic function in a large cohort of metabolically healthy obese patients. We demonstrated a direct association between BMI and the prevalence of most echocardiographic parameters of diastolic dysfunction. The cohort's size enabled categorizing patients into 4 BMI groups, as opposed to the previously studied comparison of obese versus lean. Moreover, only patients with preserved EF, in whom hemodynamics differ from patients with reduced EF, were presently included. A comparison of readmission due to heart failure between the groups failed to demonstrate a significant difference. Although absolute values were higher for morbidly obese, BMI was not a predictor of readmissions due to heart failure.

Table 3
Diastolic function assessment compared to normal BMI category.

Parameter assessed	BMI category in comparison to normal BMI	Univariable		Age and gender adjusted		Multivariable[a,b]	
		OR(95%CI)	p-Value	OR(95%CI)	p-Value	OR(95%CI)	p-Value
Left atrial volume index > 34 ml/m²	Overweight	1.2(1.1–1.4)	0.001	0.9(0.8–1.1)	0.426	1(0.8–1.2)	0.881
	Obese	1.5(1.3–1.8)	<0.001	1.1(0.9–1.3)	0.219	1(0.8–1.3)	0.769
	Morbidly obese	1.7(1.3–2.2)	<0.001	1.5(1.1–1.9)	0.008	1.5(1.1–2.2)	0.015
E/e′ > 14	Overweight	1.3(1–1.6)	0.018	1.1(0.9–1.4)	0.364	1.2(0.9–1.6)	0.143
	Obese	1.8(1.3–2.3)	<0.001	1.4(1–1.9)	0.024	1.2(0.9–1.7)	0.279
	Morbidly obese	2.3(1.5–3.4)	<0.001	1.9(1.3–3)	0.003	2.3(1.4–3.6)	0.001
e′ lateral < 10 cm/s	Overweight	2.1(1.8–2.3)	<0.001	1.7(1.5–1.9)	<0.001	1.5(1.3–1.8)	<0.001
	Obese	2.6(2.2–3)	<0.001	1.9(1.5–2.3)	<0.001	1.7(1.3–2.2)	<0.001
	Morbidly obese	2.1(1.6–2.7)	<0.001	1.7(1.2–2.3)	0.001	1.5(1.1–2.3)	0.024
e′ septal < 7 cm/s	Overweight	2.2(2–2.5)	<0.001	1.8(1.5–2)	<0.001	1.7(1.4–2)	<0.001
	Obese	2.7(2.3–3.2)	<0.001	1.9(1.6–2.3)	<0.001	2(1.5–2.6)	<0.001
	Morbidly obese	3(2.3–3.9)	<0.001	2.5(1.8–3.5)	<0.001	2.4(1.6–3.6)	<0.001
E/A ratio > 2	Overweight	0.5(0.4–0.6)	<0.001	0.8(0.6–1)	0.027	1(0.8–1.4)	0.869
	Obese	0.3(0.2–0.5)	<0.001	0.6(0.4–0.9)	0.013	1(0.7–1.6)	0.849
	Morbidly obese	0.3(0.2–0.6)	0.001	0.5(0.2–1)	0.045	0.8(0.4–1.6)	0.481
Deceleration time < 160 ms	Overweight	0.9(0.8–1)	0.045	1(0.9–1.1)	0.602	1(0.8–1.1)	0.527
	Obese	0.8(0.7–1)	0.020	0.9(0.8–1.1)	0.313	0.9(0.8–1.2)	0.617
	Morbidly obese	0.9(0.7–1.2)	0.476	1(0.8–1.3)	0.980	0.9(0.6–1.3)	0.543
Tricuspid regurgitation velocity > 2.8 m/s	Overweight	1.2(0.9–1.6)	0.147	1.1(0.8–1.4)	0.653	1(0.8–1.4)	0.920
	Obese	1.8(1.2–2.5)	0.002	1.4(1–2)	0.074	1.1(0.7–1.7)	0.634
	Morbidly obese	2.5(1.4–4.4)	0.001	2.2(1.2–4)	0.007	1.9(1–3.5)	0.054
Systolic pulmonary pressure ≥ 36 mmHg	Overweight	1(0.8–1.2)	0.937	0.8(0.7–1)	0.09	0.9(0.7–1.1)	0.423
	Obese	1.3(1–1.7)	0.024	1(0.8–1.4)	0.767	1(0.7–1.3)	0.867
	Morbidly obese	1.7(1.1–2.4)	0.008	1.3(0.9–2)	0.14	1.2(0.8–1.8)	0.491

[a] Adjusted for age, gender, renal dysfunction, and anemia.
[b] Only hospitalized patients.

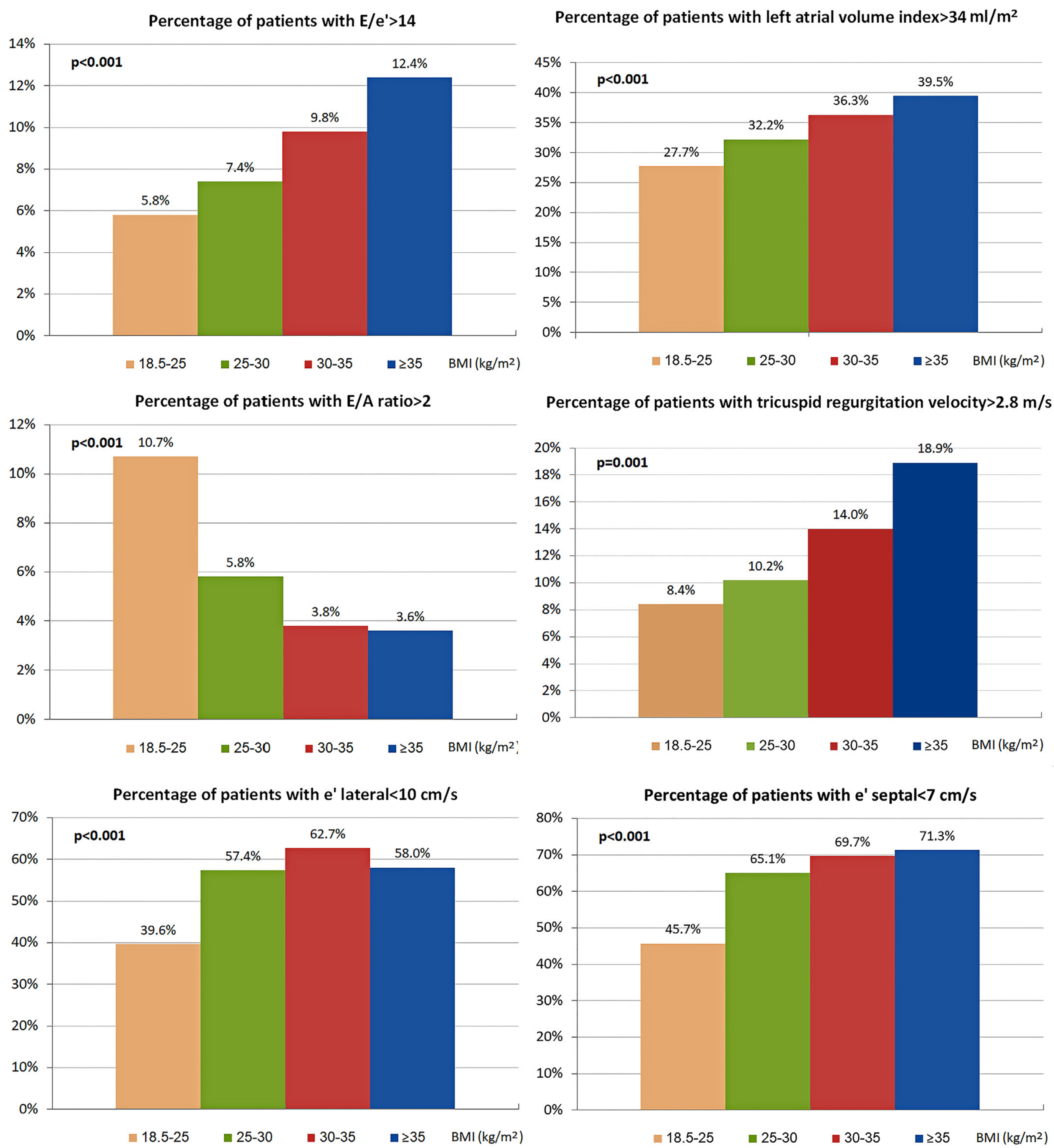

Fig. 1. Percentage of patients with abnormalities in parameters associated with diastolic dysfunction.

4.1. Left atrial volume index

The association between obesity and diastolic dysfunction is not completely understood and seems to be multifactorial. A rise in LV wall stiffness due to [21,22], and possibly regardless of [23,24] LV hypertrophy, as well as increased cardiac output without a sufficient augmentation of EF during exercise [25], are partly responsible for the rise in LV end diastolic pressure in obese. Reduced LV filling due to increased end diastolic pressure results in inadequate emptying of the left atrium. Overtime left atrial pressure rises and enlargement ensues [26]. Previous studies reported larger left atrial diameters [2,5,9,10] in metabolically healthy obese. However, left atrial volume index is currently the recommended left atrial dimension to be calculated in order to assess diastolic function [19]. A small size cohort demonstrated enlargement of left atrial volume index in obese with metabolic syndrome but not in metabolically healthy obese [11]. In the present study left atrial volume index was enlarged as BMI increased in a metabolically healthy population. The contrast might be explained by the difference in the size of the two cohorts.

4.2. Mitral annulus e′

The longitudinal motion of the mitral annulus precedes LV filling and can be reduced or delayed in instances of impaired myocardial relaxation, LV hypertrophy, or increased left atrial pressure [27]. Impaired myocardial relaxation may be explained in obesity by increased triglyceride content [7], heightened systemic oxidative stress [28] and pro-inflammatory cytokines released from or due to adipose tissue [29]. LV hypertrophy may shift contraction from longitudinal shortening to radial thickening [27]. Such mechanisms may explain the decreased mitral annulus e'. In previous, but not all [9,11] cohorts comparing diastolic function with BMI in metabolically healthy obese, lower e' was measured [3–5,10]. The lack of consistency may due to the small cohort size, as well as the averaging of e' lateral and e' septal. e' lateral and e' septal are not expected to have similar values [19] and were therefore presently differentiated. Compared to those with normal BMI, patients with higher BMIs demonstrated reduced e' of the septum and of the lateral wall.

4.3. E and A waves

The mitral valve opens when LV pressure falls below left atrial pressure. The event is marked by the initiation of passive filling (E wave), followed by late filling driven by atrial contraction (A wave). Rising LV pressure slows diastolic filling. More importantly, E/A ratio is altered in diastolic dysfunction [19]. LV Filling patterns were previously studied in association with obesity. Conflicting results were reported, with lower ratios in metabolically healthy obese in some cohorts [4,10], while no difference was reported in others [2,3,5,9,11]. A major limitation should be noted in this regard. At least three basic filling patterns exit in diastolic assessment [19]. The ranges of the E/A ratio are not ordered in a linear scale, and therefore should not be regarded as an ordinal parameter. For example, $E/A = 1$ may indicate a normal filling pattern or psuedonormal filling pattern. In the present trial we examined not only the mean values of E/A ratio according to BMI category, but also the risk for being in the normal or restrictive range. Obesity was associated with a lower risk for an abnormal E/A ratio ($E/A > 2$ - restrictive pattern). A possible explanation is the sensitivity of E/A ratio to loading conditions [30]. A higher likelihood of tricuspid regurgitation (later discussed) in patients with higher BMI categories may influence preload and subsequently mitral inflow velocities. In addition, obese patients had larger right atria (possibly due to tricuspid regurgitation and increased systolic pulmonary artery pressure), which may apply inter-atrial pressure [31] and influence preload of mitral inflow. Of note, the relation between E/A and obesity was shown only after adjustment for age and gender. Multivariable analyses did not demonstrate a significant relation.

4.4. E/e′ ratio

Consistent with previous studies [4,5,10], increased values of E/e' ratio were shown in patients with higher BMI categories. The difference was driven by the decrease in e', as discussed above.

4.5. Deceleration time

Deceleration time did not demonstrate a clear trend with regards to BMI. Previous studies reported conflicting results, with no difference in deceleration time across BMI categories in some [2,3,10,11] and a tendency for lower deceleration time values in other [9].

4.6. Tricuspid regurgitation and increased systolic pulmonary artery pressure

Increased values of tricuspid regurgitation and increased systolic pulmonary artery pressure were previously associated with obesity [32]. Another known associate of obesity is increased cardiac output (also shown presently), partly because of high metabolic activity of adipose tissue [22]. The increase in cardiac output may explain the link between BMI and systolic pulmonary artery pressure. In addition, diastolic dysfunction itself in patients with higher BMIs and the relation of obesity with obstructive sleep apnea are possible mechanisms for tricuspid regurgitation and increased systolic pulmonary artery pressure.

A previous small-scale study demonstrated the association between obesity and diastolic dysfunction among patients with up to one component of the metabolic syndrome [11]. Statistical analyses were limited due to the cohort's size, and left atrial diameter was the only parameter associated with diastolic dysfunction after adjustment for baseline characteristics. The relatively large number of individuals included in the current study enabled us to present a detailed analysis of various parameters associated with diastolic dysfunction. The entity diastolic dysfunction is not interchangeable with clinical heart failure. Although differences in diastolic function between groups were demonstrated echocardiographically, heart failure with preserved ejection fraction was not shown in terms of readmission due to heart failure. However, it should be noted that higher absolute values for readmission due to heart failure were found in morbidly obese; therefore a longer follow up or a larger cohort may be needed to test the clinical implications of the echocardiographic findings.

The current study has several limitations that warrant consideration. First, the study is retrospective; therefore all the known confounders of a retrospective study apply. Second, duration of obesity was not known. Consequently, the chronicity and long standing pathological effects, which may play a role in the extent of cardiac impairment [33], were not taken into consideration in the multivariable analyses. Third, accuracy of 2-dimensional echocardiography may be limited in certain cases related to obesity [34]. Forth, data regarding indications for echocardiography were not available. Such information may help gain a better pathophysiological understanding of the study hypothesis. Fifth, different locations of adipose tissue may have different pathological effects. One indicator of distribution of adipose tissue and a predictor of cardiovascular outcomes is the hip to waist ratio [35]. However, BMI is still the most widespread and available indicator for assessment of obesity. Additionally, while hydration status may influence diastolic assessment, a reliable fluid balance was not available in all patients. Nevertheless, the lack of hydration data applies to the entire cohort and not one group. Finally, metabolically healthy obese were shown to have higher fitness compared to their metabolically unhealthy obese counterparts [36]. Physical activity may influence diastolic function [37], and is therefore a parameter which should be accounted for. However, such data, as well as data regarding alcohol consumption [38] and illicit drug use [39] which may influence diastolic function, were not available.

In conclusion, high BMI is associated with increased risk of diastolic dysfunction even in metabolically healthy patients. Our findings suggest that obesity itself or indirect effects of adipose tissue, and not only its related metabolic comorbidities, have an effect on left ventricular structure and function. Additional trials are needed in order to evaluate whether these echocardiographic findings translate into clinical implications.

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Declarations of interest

None.

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