Clinical Medicine Insights: Cardiology

ORIGINAL RESEARCH

Impact of Overweight and Obesity on Left Ventricular Diastolic Function and Value of Tissue Doppler Echocardiography

Antoine Kossaify and Nayla Nicolas

Echocardiography Unit, Cardiology Division, USEK-University Hospital ND Secours, Byblos, Lebanon.
Corresponding author email: antoinekossaify@yahoo.com

Background: Diastolic dysfunction is a common cause of heart failure with preserved systolic function in obese patients.
Objective: To assess diastolic function in a series of overweight and obese patients using conventional and tissue Doppler echocardiography.
Setting and method: University hospital; left ventricular diastolic function was evaluated in 99 patients (mean age 61.59 ± 13.9 years); body mass index and waist circumference were assessed, and patients were subdivided into three groups according to their body mass index (kg/m^2): [normal, (18.5–24.9); overweight, (25–29.9); obese, (>29.9)]. Peak early (E) and late (A) transmitral flow and peak early (E′) diastolic mitral annulus velocities were measured.
Results: Diastolic dysfunction was significantly higher in the overweight/obese groups compared to the normal body mass index group. The analysis was made with regard to waist circumference and other clinical characteristics, and multivariate regression analysis showed a direct and independent effect of body mass index on diastolic function [OR: 2.75; CI: 1.34–5.67; $P = 0.006$]. Discussion was made in view of the latest clinical data. Also, an insight into normal weight obesity is presented and discussed.
Conclusion: Overweight and obesity are found to have an independent negative impact on diastolic function as assessed by tissue Doppler imaging.

Keywords: diastolic dysfunction, obesity, body mass index, waist circumference, tissue Doppler, echocardiography

Clinical Medicine Insights: Cardiology 2013:7 43–50

doi: 10.4137/CMC.S11156

This article is available from http://www.la-press.com.

Introduction

Diastolic dysfunction (DD) is a relatively common cardiac condition and it contributes significantly to the development of heart failure with preserved systolic function in obese patients.[1] DD is an independent predictor of mortality in patients with normal left ventricular (LV) systolic function;[2] age, female sex, obesity, hypertension and diabetes mellitus are recognized as predisposing factors for DD.[3] Overweight/obesity are common conditions encountered in daily medical practice, and it is expected that obesity will become an important cause of heart failure in the coming years.[1] More importantly, obesity is often associated with other comorbid conditions like diabetes and hypertension, which are known to be independently correlated with DD,[4] and consequently obesity is infrequently evoked—in daily practice—as an independent determinant of DD. In addition, the pathophysiological development of DD in obesity has not been fully elucidated.[5]

Whatever the underlying mechanism, the diagnosis of DD is made more difficult by obesity,[1] and conventional flow Doppler has many limitations for the assessment of DD, given that most parameters are load-dependent.[6] Conversely, tissue Doppler imaging (TDI) is a useful non-invasive tool providing accurate diagnostic and prognostic values in DD;[7] furthermore, TDI is relatively load-independent,[8,9] and this issue is of utmost importance in the setting of heart failure when loading parameters are usually disturbed.

The objectives of this study are to analyze the effect of body mass index (BMI) and waist circumference (WC) on LV diastolic function in a community-based population, while also highlighting the value of TDI for the assessment of LVDD in overweight/obese patients.

Methods

Study population

Between January and June 2012, we evaluated 132 consecutive patients visiting the outpatient echocardiography clinic at a single center in a tertiary university hospital. All patients had a medical record filled, including BMI, heart rate, blood pressure, and WC documentation along with a resting electrocardiogram tracing. Patients were eligible for inclusion if they fulfilled the following criteria: age $\geq$ 40 years, sinus rhythm, regular medical follow-up, and a signed consent form. Exclusion criteria consisted of: poor sonographic signal, acute medical illness, ejection fraction $<$ 50%, segmental wall motion abnormalities, restrictive pericarditis, severe valvular disease, pacemaker dependency, bundle branch block, atrioventricular block of any degree, and a sinus rate $>$ 120 bpm at rest. Demographic data (age, gender, and clinical status) were obtained via detailed history-taking and physical examination. Risk factors and clinical conditions were identified based on self-report of a patient's history, laboratory results, drug use, and/or medical record including previous hospital admissions. A written informed consent was obtained from all study participants and the Institutional Ethical and Research Board approved the study.

Echocardiographic assessment

Echocardiography was performed using the "iE33, Philips" system, and trained sonographers followed a standardized protocol. Conventional diastolic function assessment was performed using an apical view; transmitral flow was sampled by pulsed-wave Doppler at the level of mitral valve leaflet tips; peak velocities of the early phase (E) and late phase (A) of the mitral inflow were measured; then the ratio (E/A) was calculated. TDI was performed to measure myocardial velocities, pulsed sample volume was placed at or 5 mm within the level of the septal mitral valve annulus; early diastolic (E′) and late diastolic (A′) myocardial velocities were recorded; then the ratio E/E′ was calculated. Spectral recording was obtained at a sweep speed of 50 to 100 mm/second at end-expiration, and measurements were averaged over three consecutive cardiac cycles. Special attention is brought to the location of the sample size, as well as gain, filter, and angulations in order to obtain reliable measurements.

Criteria and measurements

Cardiac echogram was performed on a routine basis for cardiac evaluation with or without previously documented cardiac conditions. Regular medical follow-up was defined as presentation for a medical visit at least twice a year for the last 3 years, along with a minimal self-awareness of risk factors, medical conditions, and medication intake. Congestion was considered present when lower leg edema, jugular venous distension, or wet pulmonary rales were documented;

exercise intolerance was considered present if fatigue or chest discomfort appeared at minimal to moderate daily activity within the last 6 months; dyspnea was considered present if the patient reported any kind of paroxysmal or persistent breathing difficulty within the last 6 months. Weight and height were measured with participants not wearing shoes and in light clothing.

BMI was calculated as weight (kg) divided by height-squared (m^2). We divided the study participants into group 1 (control) with normal weight (BMI, 18.5–24.9 kg/m^2), group 2 with overweight (BMI, 25.0–29.9 kg/m^2), and group 3 with obesity (BMI, $\geq$ 30 kg/m^2), also we used sex-specific cut-offs to define WC as normal ($<$102 cm in men and $<$88 cm in women).[6] WC measurements were performed with the patient in a standing position, at the end of an expiratory phase with the tape placed around bare abdomen just above the hip bone. Normal weight obesity was defined as normal BMI (18.5–24.9 kg/m^2) with an abnormal WC.[10]

DD was assessed by taking into account the recommendations of the American Society of Echocardiography,[11] and by accounting for the age of the studied population. DD was considered present when septal E′ was inferior to 7 cm/second; DD was classified as mild (grade 1) when E/A $\leq$ 0.7 (impaired relaxation), moderate (grade 2) when E/A $>$ 0.7 and $\leq$1.5 (pseudo-normalized pattern), and severe (grade 3) when E/A $>$1.5 (restrictive pattern); increased filling pressure was considered present when E/E′ $>$ 15.[12]

Statistical analysis

Analysis was performed using the Statistical Package for the Social Sciences software (version 19.0). Data were expressed as the mean ± standard deviation, or the number and percentage as appropriate. Categorical variables were analyzed using the Chi-square test, first comparing all groups then using paired comparisons. Continuous variables were analyzed with Student's *t*-test or analysis of variance followed by post-hoc analysis for multiple comparisons using Tukey's test to assess different subsets as appropriate. Variables found to have significant differences in the univariate analysis were evaluated for multicollinearity and then enrolled into the multivariable logistic regression analysis (stepwise forward logistic regression). A *P*-value $<$ 0.05 was considered statistically significant.

Results

Clinical characteristics and study subjects

Out of the 132 studied subjects, 99 (mean age 61.59 ± 13.9 years, minimum 45, maximum 92) were eligible; 27 subjects had a normal BMI (group 1), 41 were overweight (group 2), and 31 were obese (group 3). Table 1 shows the clinical characteristics of each group of subjects.

Abnormal BMI (overweight/obesity) was encountered in 72 patients (72.72%), abnormal WC was encountered in nine patients (33.3%) in group 1, 25 patients (61%) in group 2, and 31 patients (100%) in group 3 [subset paired analysis: WC in group 1 $<$ WC in group 2 $<$ WC in group 3, ($P < 0.0001$)]. Out of the nine patients with normal weight obesity (group 1), two had LVDD (one impaired relaxation, one pseudonormal pattern). Of note, there was no significant difference between the groups regarding age, gender, heart rate, symptoms, and risk factors, particularly diabetes and hypertension. Moreover, and except for statin therapy, there was no significant difference regarding medication intake between the groups.

Echocardiographic results are shown in Table 2. Values of LV mass, LV mass index, and septal wall thickness (SWT) were significantly superior in overweight/obese groups compared to values in the normal group [subset paired analysis, LV mass (group 1 $<$ group 2 = group 3); LV mass index (group 1 $<$ group 2 = group 3); SWT (group 1 = group 2 $<$ group 3)]. TDI showed a significantly lower E′ in overweight/obese groups compared to the E′ in the normal BMI group ($P = 0.043$). Finally, the E/A ratio and E/E′ratio showed no significant differences; similarly, peak early (E) and late (A) transmitral diastolic flow velocities showed no significant difference among groups, though they were progressively higher from group 1 to group 3.

LVDD was encountered in 75 patients (75.75%), 16 (59.3%) patients from group 1, 32 patients (78.1%) from group 2, and 27 patients (87.1%) from group 3 ($P = 0.043$) (Table 3). Increased filling pressure was encountered in three (11.11%) patients from group 1, seven (17.07%) patients from group 2, and six (19.35%) patients from group 3.

Impaired relaxation was encountered in eight (29.62%), eleven (26.82%), and eleven (35.48%) patients from groups 1, 2, and 3, respectively. Apseudonormal pattern was encountered in

Table 1. Clinical characteristics.

Parameters	Group 1 (n = 27)	Group 2 (n = 41)	Group 3 (n = 31)	*P*-value
Age, y	62.52 ± 13.91	61.98 ± 13.52	60.26 ± 14.71	0.807
Male gender	13 (48.1)	26 (63.4)	15 (48.4)	0.329
Abnormal WC	9 (33.3)	25 (61.0)	31 (100)	<0.0001*
Heart rate, bpm	76 ± 14.97	69.44 ± 11.01	72.84 ± 11.68	0.104
Exercise intolerance	5 (18.5)	5 (12.2)	4 (12.9)	0.743
Dyspnea	13 (48.1)	19 (46.3)	16 (51.6)	0.906
Congestion	3 (11.1)	4 (9.8)	1 (3.2)	0.479
Coronary artery ds	9 (33.3)	12 (29.3)	7 (22.6)	0.652
Hypertension	13 (48.1)	20 (48.8)	17 (54.8)	0.843
Dyslipidemia	4 (14.8)	13 (31.7)	10 (32.3)	0.234
Diabetes	2 (7.4)	5 (12.2)	3 (9.7)	0.811
Medications				
Beta blockers	8 (29.6)	15 (36.6)	16 (51.6)	0.207
CC blockers	3 (11.1)	5 (12.2)	5 (16.1)	0.830
ACE-I	3 (11.1)	6 (14.6)	3 (9.7)	0.801
Diuretics	4 (14.8)	7 (17.1)	5 (16.1)	0.970
ARB	2 (7.4)	1 (2.4)	4 (12.9)	0.229
Statins	2 (7.4)	12 (29.3)	4 (12.9)	0.048*

Notes: Data are expressed as mean ± standard deviation or counts (percentage). *Significant *P*-value < 0.05.
Abbreviations: y, years; bpm, beats per minute; ds, disease; CC, calcium channel; ACE-I, angiotensin converting enzyme inhibitors; ARB, angiotensin receptor blockers.

eight (29.62%), 20 (48.78%), and 13 (41.93%) patients from groups 1, 2, and 3, respectively. The restrictive pattern was encountered in none (0%), one (2.43%), and three (9.67%) patients from groups 1, 2, and 3, respectively. Figure 1 summarizes the LVDD subtype distribution.

Univariate analysis (Table 4) showed seven variables correlated with LVDD ($P < 0.05$): age, BMI, WC, LV mass, LV mass index, SWT, and left atrial diameter. In order to identify factors with independent impact on LVDD, multivariate regression analysis was performed and it showed only two variables in the equation: increasing age and abnormal BMI [OR: 2.75; confidence interval (CI): 1.34–5.67; $P = 0.006$], (Table 5).

Discussion

In the present study, increased BMI and age were found to be independent determinants of LVDD. In addition, the prevalence and severity of LVDD was progressively higher from group 1 to group 3. Recent studies showed that increased BMI predisposes an

Table 2. Echo results according to BMI.

Echo results	Group 1 (n = 27)	Group 2 (n = 41)	Group 3 (n = 31)	*P*-value
LV mass, g	246.88 ± 73.16	310 ± 92.01	329.78 ± 118.97	0.004*
LVMI, g/m^2	144 ± 33.29	178.75 ± 46.54	178.27 ± 52.97	0.005*
SWT, mm	13.4 ± 1.91	14.76 ± 2.22	15.11 ± 3.53	0.037*
LVEDD, mm	45.85 ± 6.11	45.99 ± 5.15	46.39 ± 5.12	0.923
Ejection fraction	58.91 ± 9.21	63.55 ± 8.19	62.47 ± 7.02	0.070
LAD, mm	36.55 ± 4.72	36.95 ± 4.70	38.35 ± 4.52	0.289
E, cm/s	58.25 ± 16.05	59.86 ± 16.19	60.71 ± 18.83	0.856
A, cm/s	72.99 ± 19.43	72.44 ± 18.90	71.01 ± 23.52	0.929
E/A	0.82 ± 23	0.87 ± 31	0.90 ± 0.34	0.608
E′, cm/s	6.35 ± 2.43	5.58 ± 1.97	5.03 ± 1.46	0.043*
E/E′	10.25 ± 4.17	11.36 ± 2.97	12.35 ± 4.15	0.106

Note: *Significant *P*-value < 0.05.
Abbreviations: BMI, body mass index; LVMI, left ventricular mass index; SWT, septal wall thickness; LVEDD, left ventricular end diastolic diameter; LAD, left atrial diameter; E, peak early transmitral diastolic flow velocity; A, peak late transmitral diastolic flow velocity.

Table 3. Distribution of diastolic function (normal/abnormal) among groups.

	Group 1 (n = 27)	Group 2 (n = 41)	Group 3 (n = 31)	*P*-value
Normal diastolic function	11 (40.7%)	9 (21.9%)	4 (12.9%)	0.043
Abnormal diastolic function	16 (59.3%)	32 (78.1%)	27 (87.1%)	

Notes: Data are expressed as counts (percentage); distribution of normal and abnormal diastolic function among groups.

individual to DD, with special highlights on the role of TDI for the assessment of diastolic function in obesity.[13,14] LVDD was encountered in 59.3% of subjects with a normal BMI, and we hypothesize that this finding is related to other associated factors involved in DD, such as aging.

Many substances (angiotensin 2, leptin, resistin, adiponectin …) are secreted by adipocytes and exert a direct or indirect detrimental effect on the myocardium, and predispose an individual to both LVDD and diastolic heart failure.[15] In this study, increased filling pressure was more prevalent in group 3; nevertheless, this difference was not statistically significant and we estimate that E/E′ (marker of increased filling pressure) reflects more diastolic heart failure rather than LVDD. Adiponectin deficiency in obesity contributes to myocyte apoptosis, precipitating abnormal relaxation, and can lead to adiposity-related DD.[16] Similarly, angiotensin 2 and leptin exert a fibrotic effect on the intercellular matrix leading to DD.[17]

Overweight/obese patients with impaired glucose tolerance show abnormal uptake of calcium by the sarcoplasmic reticulum, leading to prolonged isovolumic relaxation time.[18] In this study, there was no independent correlation demonstrated between LVDD and diabetes, coronary artery disease, or hypertension.

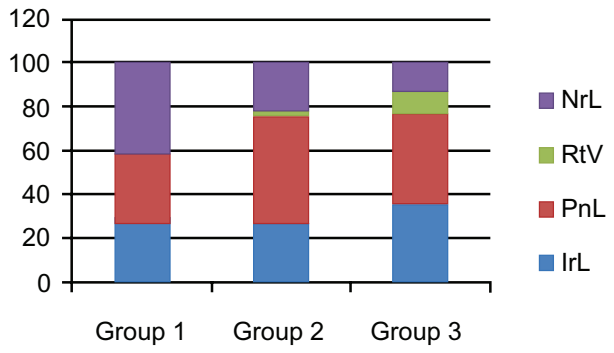

Figure 1. Distribution of LVDD subtypes among each group.
Note: Horizontal line, group; vertical line, normal diastolic function percentage and subtypes of LVDD percentage (%).
Abbreviations: LVDD, left ventricular diastolic dysfunction; Nrl, Normal; IrL, impaired relaxation; PnL, pseudonormal pattern; RtV, restrictive pattern.

We estimate that disease history (duration, severity, management, and so on) has a significant impact on the potential development of complications like LVDD. This factor was not documented in the study (beyond the design and objective). In addition, patients with these conditions form small subgroups, likely yielding low statistical power.

In this study, abnormal WC was found to be directly correlated with BMI ($P < 0.0001$) and with LVDD ($P = 0.035$). Nevertheless, WC was not found to be an independent determinant of LVDD, and this is discordant with previously reported data.[19,20] Normal weight obesity (normal BMI, abnormal WC) was encountered in only nine subjects, and only two of them had LVDD. With such a small number, we hypothesize that the statistical power was insufficient to demonstrate an independent impact of normal weight obesity on LVDD. Moreover, in the definition of normal weight obesity, we adopted the criteria "normal BMI with abnormal WC"; fat distribution and concentration were not assessed with markers like waist-to-hip ratio or percentage of body fat.

In the absence of LVDD, left atrial enlargement in overweight/obese subjects correlates with the anthropometric variables and reflects a "physiological" adaptation of the heart to an obese state.[21] Conversely, in patients with LVDD, left atrial enlargement may be the consequence of chronic LV pressure elevation, and in this case, indexed left atrial volume (>34 mL/m^2) is more reliable than indexed left atrial diameter as a marker of LVDD.[22] In the present study, there was no significant difference in left atrial diameter among the three groups, and we hypothesize—as mentioned above—that the indexed volume is a better marker of left atrial remodeling in this setting.

When LVDD is absent, a mild structural LV remodeling (hypertrophy) in overweight/obese patients may indicate a state of "physiological" adaptation of the heart to obesity, and TDI is crucial in these cases to differentiate "physiological" LV hypertrophy from pathological LV hypertrophy with LVDD.[23] In the

Table 4. Studied variables according to diastolic function results.

Variables	DD absent (E′ ≥ 7)	DD present (E′ < 7)	*P*-value
Age, Y	53 ± 12.85	64.33 ± 13.14	<0.0001*
Gender			
Male	14 (25.9%)	40 (74.1%)	0.847
Female	10 (22.2%)	35 (77.8%)	
Abnormal BMI	13 (18.1%)	59 (81.9%)	0.037*
Abnormal WC	11 (16.9%)	54 (83.1%)	0.035*
Diabetes	1 (10%)	9 (90%)	0.472
Hypertension	10 (20%)	40 (80%)	0.447
Coronary artery ds	5 (17.9%)	23 (82.1%)	0.502
Dyslipidemia	3 (11.1%)	24 (88.9%)	0.109
Heart rate, bpm	71.08 ± 9.55	72.68 ± 13.42	0.591
Medications			
Beta blockers	7 (17.9%)	32 (82.1%)	0.348
CC blockers	2 (15.4%)	11 (84.6%)	0.651
ACE-I	1 (8.3%)	11 (91.7%)	0.311
Diuretics	1 (6.3%)	15 (93.8%)	0.130
ARB	3 (42.9%)	4 (57.1%)	0.463
Statins	2 (11.1%)	16 (88.9%)	0.257
Echo data			
LV Mass, g	249.33 ± 76.72	314.87 ± 103.75	0.002*
LVMI, g/m2	142.91 ± 32.29	177.51 ± 48.95	0.002*
SWT, mm	13.25 ± 1.98	14.9 ± 2.78	0.009*
LVEDD, mm	45.72 ± 5.73	46.19 ± 5.28	0.710
Ejection fraction	64.64 ± 8.92	61.08 ± 7.94	0.067
LAD, mm	35.58 ± 4.44	37.82 ± 44.63	0.040*

Notes: Data are expressed as the mean ± standard deviationor counts (percentage). *Significant *P*-value < 0.05.
Abbreviations: Y, years; ds, disease; bpm, beats per minute; CC, calcium channel; ACE-I, angiotensin converting enzyme inhibitors; ARB, angiotensin receptor blockers; LVMI, LV mass index; SWT, septal wall thickness; LVEDD, LV end diastolic diameter; LAD, left atrial diameter.

present study, changes in heart structure (LV mass, LV mass index, SWT, and left atrial diameter) were present in the LVDD group; these changes did not show any independent correlation with LVDD in multivariate analysis and we estimate that they are consecutive to increased BMI,[22,23] rather than as a consequence of LVDD. In addition, we hypothesize that significant structural changes occur at the stage of diastolic heart failure with increased filling pressure rather than with LVDD.

Mean heart rate showed no significant difference among the three groups ($P = 0.591$).We hypothesize that this finding is related to the study design (effect of medications, rate > 120 bpm not included).We also assume that the significant increase in heart rate is a finding in diastolic heart failure rather than LVDD. Similarly, there was no significant difference in dyspnea and exercise intolerance among the groups; we explain this finding by the fact that patients with LVDD are not necessarily at the stage of symptomatic diastolic heart failure. A mild difference in statin therapy among the groups was found (higher in groups 2 and 3; $P = 0.048$).This is a logical finding given that dyslipidemia was more prevalent in these groups, and accordingly more patients are likely taking statins.

Table 5. Multivariate regression analysis.

Variables	OR	95% CI		*P* value
		Lower limit	Upper limit	
BMI	2.75	1.34	5.67	0.006
Age	1.08	1.04	1.12	<0.0001
Constant	0.02			0.002

Abbreviations: CI, confidence interval; OR, odds ratio.

Early diastolic annulus/tissue velocity is crucial for the assessment of DD. E′ is not affected by loading factors or by physiological changes like respiration; values of E′ < 8.5 cm/second at the lateral site and <8 cm/second at the septal site have been suggested as cut-off values for the diagnosis of LVDD by many authors.[11] In the present study,

we adopted the values used by Russo et al,[12] who considered that LVDD was present when E′ < 7 cm/second, taking into consideration the average age of the studied population. Also E and A were used for LVDD subtype classification. E′ is better measured at both levels (septal and lateral averaged).[12] Nevertheless, many authors adopted only the septal level, and we mentioned this issue as a limitation in this study.[24]

Kasner et al[25] did not find any relevant diastolic index or parameter acquired with conventional Doppler echocardiography sufficient enough to make an accurate diagnosis of DD. Early (E) and late (A) diastolic flow velocities, E/A ratio, isovolumic relaxation time, mitral deceleration time, A duration, and pulmonary venous flow correlate weakly with relaxation anomalies and do not allow for an accurate assessment of stiffness or filling pressure. Consequently, the authors concluded that conventional Doppler is of limited value for the detection of DD, and so TDI is more reliable and accurate from this perspective.

Other echographic parameters may have additional value for diastolic function assessment:[11] diastasis peak velocity, left atrial size, color M-mode flow propagation, Valsalva maneuver, filling time, and color-coded TDI. However, acquiring these additional parameters is time-consuming, color M-mode flow and pulmonary venous flow recording is often technically challenging, and the Valsalva maneuver is not standardized and is often difficult to achieve reliably. In summary, these additional parameters are to be considered on a case-by-case basis when basic TDI is not conclusive, especially in obese patients when echographic signal is poor.

Clinical implications

BMI and WC should be assessed more frequently for identifying subjects who are at risk of developing DD and who are likely to benefit from efficient measures like weight reduction or physical rehabilitation.[26] With weight reduction, there is a reverse of cardiac remodeling that occurs along with improvement in diastolic function.[27]

TDI can detect asymptomatic LVDD and subsequently help to apply preventive and therapeutic measures early before progression of the condition. Heart failure is a common cardiac condition with poor prognosis despite all of the current management strategies available; accordingly, overweight/obesity (if any) control should be considered a priority in the multifaceted management plan of systolic and diastolic heart failure.[28] Moreover, an E/E′ ratio > 15 and an E′ value of <3 cm/second are markers of poor prognosis; therefore, management must be adapted accordingly.[11]

The TDI technique is relatively simple to perform. It has been proven to provide an accurate diagnostic and prognostic value in LVDD, and therefore we estimate that its regular use in daily practice is essential.

Limitations

This study is monocentric and cross-sectional, and the studied population size is limited. E′ was assessed only at the septal annular or basal septal site, although measurement at the lateral and at the septal site (then averaging) is more valuable. We sought to examine an "unselected" group of subjects who would be representative of a broader population; however, most patients in this study were referred for clinically suspected or documented preexisting cardiovascular conditions, and as such they represent a group of patients with a high prevalence of cardiac disease.

Acknowledgement

The authors would like to express their gratitude to all StarPool team for contributing to the realization of this manuscript.

Author Contributions

Conceived and designed the experiments: AK. Analyzed the data: AK, NN. Wrote the first draft of the manuscript: AK, NN. Contributed to the writing of the manuscript: AK, NN. Agree with manuscript results and conclusions: AK, NN. Jointly developed the structure and arguments for the paper: AK, NN. Made critical revisions and approved final version: AK, NN. All authors reviewed and approved of the final manuscript.

Funding

Author(s) disclose no funding sources.

Competing Interests

Author(s) disclose no potential conflicts of interest.

Disclosure and Ethics

As a requirement of publication, the author(s) have provided to the publisher signed confirmation of compliance with legal and ethical obligations including but not limited to the following: authorship and contributorship, conflicts of interest, privacy and confidentiality, and (where applicable) protection of human and animal research subjects. The authors have read and confirmed their agreement with the ICMJE authorship and conflict of interest criteria. The authors have also confirmed that this article is unique and not under consideration or published in any other publication, and that they have permission from rights holders to reproduce any copyrighted material. Any disclosures are made in this section. The external blind peer reviewers report no conflicts of interest.

References

1. Galinier M, Pathak A, Roncalli J, Massabuau P. Obesity and cardiac failure. *Arch Mal Coeur Vaiss*. 2005;98(1):39–45. French.
2. Aljaroudi W, Alraies MC, Halley C, et al. Impact of progression of diastolic dysfunction on mortality in patients with normal ejection fraction. *Circulation*. 2012;125(6):782–8.
3. Kazik A, Wilczek K, Poloński L. Management of diastolic heart failure. *Cardiol J*. 2010;17(6):558–65.
4. Russo C, Jin Z, Homma S, et al. Effect of diabetes and hypertension on left ventricular diastolic function in a high-risk population without evidence of heart disease. *Eur J Heart Fail*. 2010;12(5):454–61.
5. InterAct Consortium, Langenberg C, Sharp SJ, et al. Long-termrisk of incident type 2 diabetes and measures of overall and regionalobesity: the EPIC-InterActcase-cohortstudy. *PLoS Med*. 2012;9(6):e1001230.
6. Redfield MM, Jacobsen SJ, Burnett JC Jr, Mahoney DW, Bailey KR, Rodeheffer RJ. Burden of systolic and diastolic ventricular dysfunction in the community: appreciating the scope of the heart failure epidemic. *JAMA*. 2003;289(2):194–202.
7. Yu CM, Sanderson JE, Marwick TH, Oh JK. Tissue Doppler imaging a new prognosticator for cardiovascular diseases. *J Am Coll Cardiol*. 2007;49(19):1903–14.
8. Yalçin F, Kaftan A, Muderrisoğlu H, et al. Is Doppler tissue velocity during early left ventricular filling preload independent? *Heart*. 2002;87(4):336–9.
9. Sohn DW, Chai IH, Lee DJ, et al. Assessment of mitral annulus velocity by Doppler tissue imaging in the evaluation of left ventricular diastolic function. *J Am Coll Cardiol*. 1997;30(2):474–80.
10. Kosmala W, Jedrzejuk D, Derzhko R, Przewlocka-Kosmala M, Mysiak A, Bednarek-Tupikowska G. Left ventricular function impairment in patients with normal-weight obesity: contribution of abdominal fat deposition, profibrotic state, reduced insulin sensitivity, and proinflammatory activation. *Circ Cardiovasc Imaging*. 2012;5(3):349–56.
11. Nagueh SF, Appleton CP, Gillebert TC, et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. *Eur J Echocardiogr*. 2009;10(2):165–93.
12. Russo C, Jin Z, Homma S, et al. Effect of obesity and overweight on left ventricular diastolic function: a community-based study in an elderly cohort. *J Am Coll Cardiol*. 2011;57(12):1368–74.
13. Cil H, Bulur S, Türker Y, et al; for MELEN Investigators. Impact of body mass index on left ventricular diastolicdysfunction. *Echocardiography*. 2012;29(6):647–51.
14. Tanalp AC, Bitigen A, Cevik C, et al. The role of tissue Doppler study in the assessment of left ventricular dysfunction in obesity. *Acta Cardiol*. 2008;63(5):541–6.
15. Galderisi M. Diastolic dysfunction and diastolic heart failure: diagnostic, prognostic and therapeutic aspects. *Cardiovasc Ultrasound*. 2005;3:9.
16. Negi SI, Jeong EM, Shukrullah I, Raicu M, Dudley SC Jr. Association of low plasma adiponectin with early diastolicdysfunction. *Congest Heart Fail*. 2012;18(4):187–91.
17. Zibadi S, Cordova F, Slack EH, Watson RR, Larson DF. Leptin's regulation of obesity-induced cardiac extracellular matrix remodeling. *Cardiovasc Toxicol*. 2011;11(4):325–33.
18. Shimabukuro M, Higa N, Asahi T, et al. Impaired glucose tolerance, but not impaired fasting glucose, underlies left ventricular diastolicdysfunction. *Diabetes Care*. 2011;34(3):686–90.
19. Canepa M, Strait JB, Abramov D, et al. Contribution of central adiposity to left ventricular diastolic function. *Am J Cardiol*. 2012;109(8):1171–8.
20. Koç F, Tokaç M, Kaya C, et al. Diastolic functions and myocardial performance index in obese patients with or without metabolic syndrome: a tissue Doppler study. *Turk Kardiyol Dern Ars*. 2010;38(6):400–4.
21. Sasson Z, Rasooly Y, Gupta R, Rasooly I. Left atrial enlargement in healthy obese: prevalence and relation to left ventricular mass and diastolic function. *Can J Cardiol*. 1996;12(3):257–63.
22. Jorge AJ, Ribeiro ML, Rosa ML, et al. Left atrium measurement in patients suspected of having heart failure with preserved ejection fraction. *Arq Bras Cardiol*. 2012;98(2):175–81.
23. Chadha DS, Gupta N, Goel K, et al. Impact of obesity on the left ventricular functions and morphology of healthy Asian Indians. *Metab Syndr Relat Disord*. 2009;7(2):151–8.
24. Kim H, Yoon HJ, Park HS, et al. Usefulness of tissue Doppler imaging-myocardial performance index in the evaluation of diastolic dysfunction and heart failure with preserved ejection fraction. *Clin Cardiol*. 2011;34(8):494–9.
25. Kasner M, Westermann D, Steendijk P, et al. Utility of Doppler echocardiography and tissue Doppler imaging in the estimation of diastolic function in heart failure with normal ejection fraction: a comparative Doppler-conductance catheterization study. *Circulation*. 2007;116(6):637–47.
26. Schuster I, Vinet A, Karpoff L, et al. Diastolic dysfunction and intraventricular dyssynchrony are restored by low intensity exercise training in obese men. *Obesity*. 2012;20(1):134–40.
27. Lakhani M, Fein S. Effects of obesity and subsequent weight reduction on left ventricular function. *Cardiol Rev*. 2011;19(1):1–4.
28. Powell BD, Redfield MM, Bybee KA, Freeman WK, Rihal CS. Association of obesity with left ventricular remodeling and diastolic dysfunction in patients without coronary artery disease. *Am J Cardiol*. 2006;98(1):116–20.