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Assessment of Left Arterial Function by using 2-Dimensional Speckle Tracking in Obese versus Non-Obese Diabetic Patients

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Abstract

Both obesity and diabetes are major problems for the public's health. Both are known to contribute to the development of atrial cardiomyopathy. However, the consequences of obesity on the function of the left atrium(LA) in diabetic individuals have not been determined as of yet. The aim of this study is to compare the peak atrial longitudinal strain (PALS) measured by two-dimensional (2D) speckle tracking in obese versus non-obese diabetic Iraqi patients. For a study that was designed to be cross-sectional, the data collection period lasted for a total of ten months. In this study, the participants had to have diabetes mellitus type 2. A comparison was made between patients who were obese and patients who were not obese using 2-D speckle tracking to measure the peak left atrial longitudinal strain. Several additional factors, such as age, gender, body mass index, conventional echocardiographic parameters, and volume-derived LA function, were investigated during this study. A total of 59 patients participated in this study. The ratio of males to females was exactly 1:1.5, and the average age was (54 ± 9.4) years old. Coexistent systemic arterial hypertension was observed in 25 % of the study population. Patients with type 2 diabetes mellitus and obesity had ad higher E/e` ratio and lower PALS than patients with type 2 diabetes mellitus without obesity, whereas all other parameters were statistically non-significant (EF, E/A, S prime, LA volume index). It was found that the peak longitudinal strain of the LA, which was measured using 2-D speckle tracking, was lower in the obese diabetic individuals. This was in contrast to diabetic people, who did not have obesity issues. An evaluation of the global strain in the left atrium can help in the early detection of remodeling and dysfunction in the left atrium if it is compared to the size of the left atrium and the filling pressures of the left ventricle, both of which are respectively determined by the E/e' ratio and the left atrial volume.

Keywords: Obesity, type 2 diabetes mellitus, Left atrial, Two-dimensional speckle-tracking echocardiography.

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تقييم وظيفة الذين الايسر باستخدام تتبع البقعه ثنائية الابعاد في مرضى السكري الذين يعانون من السمنه وبدونها

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الخلاصة

السمنة ومرض السكري من عوامل الخطر لاعتلال عضلة القلب الاذيني، وبالتالي يعتبران من مشاكل الصحة العامة . ومع ذلك ، فإن تأثيرات السمنة على وظيفة الأذين الايسر لدى مرضى السكري لم يتم تحديدها بعد. الهدف من الدراسة هو المقارنه بين ذروة الاجهاد الطولي الاذيني (PALS) التي تم قياسها عن طريق التتبع البقعي الثنائي الابعاد في مرضى السكري الذين يعانون من السمنة مقابل غير المصابين بالسمنة . اجرينا دراسة مقطعيه خلال فترة عشرة اشهر. شملت مرضى يعانون من داء السكري من النوع الثاني ، تمت مقارنة ذروة الاجهاد الطولي الاذيني الايسر عن طريق تتبع البقعة ثنائية الابعاد بين مرضى يعانون من السمنة ومرضى لايعانون من السمنة. تضمنت المتغيرات الاخرى التي تم تقييمها خلال هذه الدراسة العمر، الجنس، مؤشر كتلة الجسم معايير تخطيط صدى القلب القياسية ووظيفة الاذين الايسر المشتقة من الحجم. شملت هذه الدراسة 59 مريضا ، كان متوسط العمر (54 ±9.4) سنه ،وكانت نسبة الذكور/الاناث 1.5:1 لوحظ ارتفاع ضغط الدم الشرياني المصاحب في 25 % من مجموع المشتركين. كانت نسبة (`E/e) اعلى وقيمة (PALS) اقل في المرضى الذين يعانون من داء السكري من النوع الثاني والسمنة مقارنة بالمرضى الذين يعانون من داء السكري النوع الثاني دون السمنة، في حين باقي المتغيرات (S prime ,E /A, EF, LA VI) كانت غير ذات دلاله إحصائية. الاستنتاج : ان ذروة السلالة الطولية من الاذين الايسر كما تم تقييمها بواسطة تتبع البقعه ثنائية الابعاد قد انخفضت في مرضى السمنة المصابين بداء السكري مقارنة مع مرضى السكري غير البدينين . يسمح تقييم سلالة الاذين الايسر بالكشف المبكر عن اعادة تشكيل الاذين الايسر والاختلال الوظيفي بالمقارنة مع حجم الاذين الايسر وضغط ملئ البطين الايسر الذي يحدده حجم الاذين الايسر ونسبة `E/e على التوالي.

1. Introduction

Obesity has spread worldwide during the last 20 years, affecting both children and adults. Despite extensive studies into the connection between obesity and cardiovascular diseases (CV), many unanswered problems still exist [1]. Obesity, for example, has been associated with various cardiovascular diseases and conditions, including atherosclerosis, symptomatic coronary artery disease (CAD), heart failure (HF), and atrial fibrillation. Obesity indirectly elevates the cardiovascular diseases risks because of its effect on the development and severity of comorbid conditions such as hypertension, dyslipidemia, glucose intolerance, and diabetes [2].

A well-known cardiovascular risk factor associated to cardiovascular morbidity and mortality is type 2 diabetes mellitus. Myocardial deformation assessment gives important information regarding small changes in heart function that may be used to predict cardiovascular morbidity and mortality [3]. Several studies have used the benefit of strain analysis in diabetic patients to assess left ventricular(LV) deformation [4]. Since recent studies showed that the left atrium (LA) function and structure were powerful and independent predictors of cardiovascular events, and since comparable findings have been duplicated in diabetic patients who do not have a previous history of cardiovascular disease, researching how the LA works have become even more important [5].

Studies have shown a strong correlation between weight and type 2 diabetes mellitus (T2DM), with obese people having the highest risk of getting the disease; the vast majority of type 2 diabetes patients are overweight or obese. It was determined that a patient is obese if his body mass index (BMI) was greater than 30 kilograms per square meter [6,7].
Two-Dimensional Speckle-Tracking Echocardiography (2DSTE) is used to evaluate the longitudinal deformation in the left anterior myocardium. It is an acceptable and reliable method for assessing the function of the LA. It is an angle-independent method compared with color-coded 2-D tissue Doppler imaging, making it feasible to detect LA impairment in diabetic patients [8].
This study compares the peak atrial longitudinal strain (PALS) measured by 2D speckle tracking in obese versus non-obese diabetic patients.

2. Materials and methods

2.1 Study population

This cross-sectional observational study was undertaken between October 2020 and July 2021 at the echocardiography unit of Baghdad Teaching Hospital. It included 59 patients who were referred to the hospital for multiple causes. An LV ejection fraction percentage of greater than 50%, type 2 DM, sinus rhythm, and informed consent were the inclusion criteria. Patients with significant coronary artery disease (defined as a history of MI or revascularization, significant Wall Motion Abnormality (WMA) on echocardiography, or a positive stress test of any kind) were excluded from the study. Other exclusion criteria included mitral and aortic valve disease, atrial fibrillation or flutter, any type of cardiomyopathy (dilated, ischemic, or hypertrophic), and poor echocardiographic views.
Patients with BMI of 30 kg/m^2 or more were considered obese. According to the American Diabetes Association's guidelines [9], diabetes was defined as having a minimum fasting blood sugar level of 126 mg/dL in 2 different samples or patients using either insulin or oral antidiabetic medications. The patient's medical history was used to determine the type of diabetes. Antihypertensive medication use or two different blood pressure readings that were at least 140 mmHg systole and/or 90 mmHg diastole were required to consider the patients as hypertensive.

All the study participants had anthropometric measurements (height and weight) and laboratory tests (fasting glucose level, HbA1c, total cholesterol, triglycerides, and C reactive protein). Each patient's body mass index and Body Surface Area (BSA) were determined. The study gained ethical approval from the ethical committee of the Department of Medicine/ College of Medicine /University of Baghdad, and the research was authorized to proceed. Before collecting any data each patient's explicit consent was obtained.

2.2 Echocardiography

All echocardiographic examinations, including 2DSTE, were performed with Doppler studies using a (PHILIPS CX50 ultrasound USA) machine with a 3.5-MHz multiphase array probe on subjects in a left lateral decubitus position. One-lead electrocardiography monitor was used to check the patient rhythm and determine the timing of the cardiac cycle to display the different atrial phases. The 2-chamber and 4-chamber apical images of the LA were utilized to compute the volume of the LA, using the biplane Simpson approach.

The end-systolic and end-diastolic volumes of the left ventricle were measured in the apical 2- and 4-chamber views of the heart using a modified version of Simpson's method

[10]. Pulsed wave Doppler imaging was utilized to acquire the peak velocity of the mitral flow at early (E) and late (A) diastole, as well as the peak wave velocity of the lateral and septal mitral annuli at systole (s') and at early (e') and late (a') diastole in the apical 4-chamber view. The results were then calculated by averaging the readings over three cardiac cycles. The average values of the septal and lateral mitral annuli were then recorded, and E/ (the average of the e' values of the septal and lateral mitral annuli) was calculated. All of these measurements were performed in accordance with the American Society of Echocardiography's recommendations [11].

At the end of the expiration, three consecutive cardiac cycles were acquired in apical 2- and 4-chamber views at a frame rate of between 50 and 60 per second for 2DSTE. These cardiac cycles were digitally recorded in the setup for subsequent analysis. It was decided not to include the pulmonary veins or the left atrial appendage. The study was carried out using of the QLAB 11 program, which featured a CMQ option that was developed specifically for 2DSTE.

2.3 Statistical Analysis

All statistical analyses were performed using version 26 of Statistical Package for the Social Sciences (SPSS). Simple measurements of frequency, percentage, mean, standard deviation, and range were used to present the data (minimum-maximum values).
Using the Pearson Chi-square test, the significance of the difference in percentages (qualitative data) was determined. Statistical significance was evaluated when the P value was less than or equal to 0.05.

3. Results

3.1 Demographic and clinical characteristics of study participants

The current study was performed on 59 patients, with a mean age of 54.80 years old with a standard deviation of 9.474 years, and the majority was distributed between 50–64 years old (64.4%). The group with ages ranging from 34–49 constituted (27.1%). The remaining group, which included patients older than 64 years were (8.5%), Table 1.
Almost 60% of the subjects were women; approximately one-half had diabetes, and one-fourth had both diabetes and hypertension. The study populations were equally distributed between obesity and non-obesity. Table1 lists the demographic and clinical characteristics of the participants.

Table 1: Participants' demographic and clinical characteristics (N=59)

Demographic characteristics	Number (N = 59)	
Age (year)	34-49	16
	50-64	38
	>64	5
Sex	Male	22
	Female	37
BMI (kg/m^2)	Non obese	30
	Obese	29
Co-morbidities	No known morbidity	10
	DM	32
	Hypertension + DM	17

Table 2 shows the relation between demographic characteristics in both obese and non-obese patients. It shows that there was a statistically significant difference for (sex, weight, height, BMI, and BSA) with p-values of (0.003, 0.0005, 0.017, 0.013, 0.007) respectively, whereas other parameters, including age and comorbidities, showed insignificant differences.

Table 2: Demographic characteristics in both obese and non-obese patients (N=59)

Demographic characteristics		Non-Obese patients (N = 30)	Obese patients (N = 29)	p-value
Age (year)		53.50±8.46	56.14±10.39	0.135
Male sex (%)		14	8	0.003
Weight (kg)		73.40±17.66	88.17±9.38	0.0005
Height (m)		168±10.61	164.10±7.16	0.017
BMI (kg/m^2)		26.22±2.09	32.55±2.56	0.013
BSA(m^2)		1.81±0.203	1.92±0.128	0.0071
Co-morbidities	DM(%)	20	29	0.062
	HTN (%)	9	8	0.126

Figure 1 demonstrates that almost 59% of the diabetic patients were obese, and 29% were overweight.

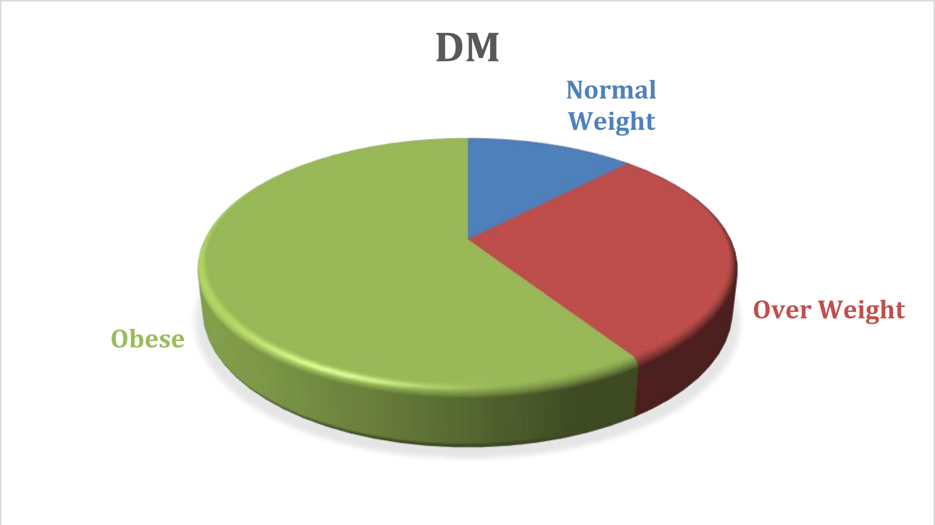

Figure 1: The BMI distribution in diabetic patient.

Based on Table 3, it is evident that E/e` and LA strain show statistically significant differences (p-value > 0.05) between obese and non-obese patients, whereas all other parameters (EF, E/A, S prime, LA volume index) show no significant difference.

Table 3: Distribution of the Echo parameters according to studied groups (obese versus non obese) (N = 59).

Echo parameters	Non-Obese patients (N = 30)	Obese patients (N = 29)	p-value
EF	61.63±3.624	62.93±3.369	0.348
E/A	1.120±0.367	1.179±0.391	0.365
E/e`	8.03±1.426	10.45±2.284	0.006
S prime	13.23±2.373	12.72±2.576	0.328
LA strain	29.90±7.078	22.69±5.478	0.008
LA volume index	23.00±5.705	25.93±7.040	0.128

Figure 2 illustrates the percentage of patients with diastolic dysfunction with and without obesity; (66%) of the non-obese group were of normal diastolic function. In comparison, it was (31%) of the obese group. On the other hand, obese patients were more likely to have grade 1 diastolic dysfunction. This percentage increases dramatically with grade 1 diastolic dysfunction compared to non-obese groups (55.1% versus 33%. Grade 2 diastolic dysfunction was seen only in (13.7%) of the obese group.

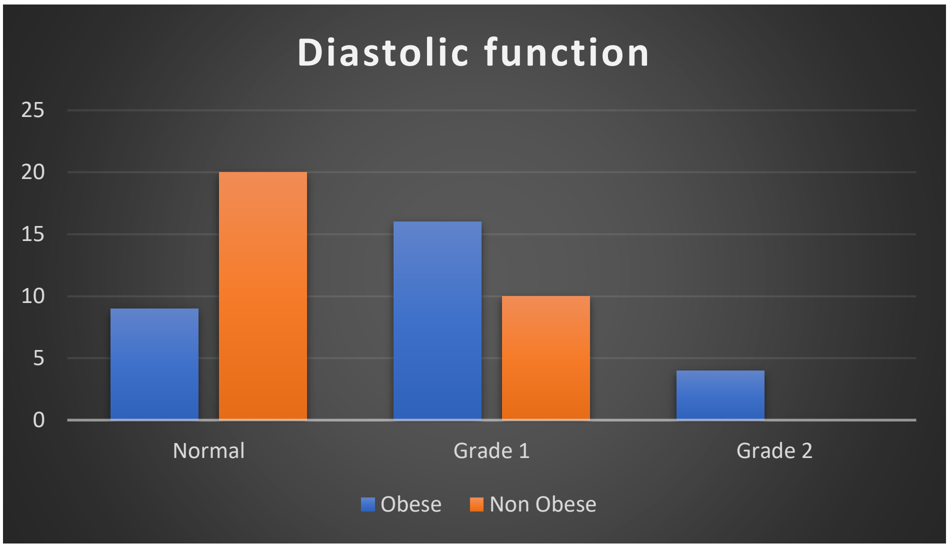

Figure 2: Distribution of diastolic function in the study population according to presence or absence of obesity.

4. Discussion

By analyzing the longitudinal deformation of the LA myocardium with 2DSTE, we could study the function of the LA in adult patients who had type 2 diabetes with or without obesity. This allowed us to evaluate how the patients' LA function altered throughout their treatment. According to the findings of Peter Blomstrand et al., patients with diabetes and obesity had a higher body mass index (BMI) as well as a bigger body surface area (BSA) [13].

According to the findings of our research, a higher E/é ratio is connected with a higher prevalence of obesity. This finding is in agreement with those of Cil et al. [14], which found that obesity was a contributor to LV dilatation, hypertrophy, poor relaxation, and diastolic dysfunction. These results are also compatible with the findings of Arnold et al. [15].

We found that LA strain was lower in obese patients compared with non-obese and this result is consistent with the result of Julio et al. [16] who found that obesity was associated with impaired longitudinal LA strain. While Peter Blomstrand et al. [13] found that the LA strain was of insignificant difference between obese and non-obese patients.

In this study, the ejection fraction was almost the same in the obese and the non-obese. This result was the same as that reported by Wang et al. [17], who identified an association between obesity and subclinical impairment of both the systolic and diastolic functions, whereas Peter Blomstrand et al. [13] showed a substantial link between obesity and impaired LV systolic function as measured by LVEF. The discrepancies between our results and those of other studies may be related to the exclusion of patients with low LVEF or established cardiovascular disease from our study.

Concerning the E/A, we did not find any significant correlation between obese and non-obese groups; however, Movahed et al. [18] did find such an association as they found that a reversal of the E/A ratio occurred more frequently in patients whose BMI was higher. This disparity may be attributable to the difference in sample size, as Movahed et al. study included 13,382 participants, but our research involved only 59 individuals.

Again, there was no statistically significant difference between S prime in both obese and non-obese groups in our study, and this was the same result found by Taşolar et al. [19]. However, the result mentioned by Barbosa et al. [20] showed that there was a significantly lower S prime in the obese group; this difference might be due to the exclusion of patients with systolic dysfunction in our study. Again, this was the same result found by Taşolar et al. [19].

For the LA volume index, our study found no difference between obese and non-obese patients, which may have been due to geometrical assumptions in the calculation of the LA because we calculated the LAV in 2D, but the third dimension was lacking. The same result was reported by Antonello D' Andrea et al. [21] that there was no significant association between LAV index and BMI. Tadic et al. [22] observed an increase in the LAV index in their obese hypertensive group; this disparity may be due to the younger age group and a higher proportion of males in his sample compared to ours. In our study, most patients had a normal LAV index, despite the fact that the LAV index was not a requirement for patient inclusion.

According to the findings of our research, the diastolic function of patients was significantly related to their body mass index (BMI). While the majority of non-obese patients (66%) had normal diastolic function, only 31% of obese patients had normal diastolic function. Furthermore, this percentage increased with the grade of diastolic dysfunction as we observed that grade 2 diastolic dysfunction occurred only in obese patients. Powell et al. came to the same conclusion [23]. We discovered that approximately 29% of diabetic patients were overweight, and this number was roughly the same as what Esteghamati et al. [24] reported, which was approximately 33.7% of diabetic patients being overweight. On the other hand, our research indicated that almost 59% of diabetes patients were obese, although the rate of obese diabetic patients was just 10.2% in another study [24].

5. Conclusions

The following were concluded from this study:

1. Obese diabetic individuals had a lower peak atrial longitudinal strain, as measured by 2D speckle tracking, in comparison to diabetic patients who were not obese.
2. The evaluation of LA global strain enables the early diagnosis of LA remodeling and dysfunction by comparison to LA size and LV filling pressures, which are, respectively, dictated by LA volume and E/e' ratio.

6. Disclosure and conflict of interest

There are no conflicts of interest.

References

[1] K. Flegal, M. Carroll, B. Kit and C. Ogden, "Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010," *JAMA*, vol. 307, pp.491–7, 2012.

[2] P. Poirier, T. Giles and G. Bray, "Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss," *Circulation*, vol. 113, pp. 898–918, 2006.

[3] S. I. Essa and H. H. Abed, “Assessment of the Left Ventricular Mass (LVM) among Patients with Diabetes in Relation to Age Using Doppler Echocardiography," *World Heart Journal*, vol. 11, no. 3, pp. 239-244, 2019.

[4] M. F. Hussein, S. I. Essa and A. Z. Saleh, "Evaluation of Myocardial Performance in Hypertensive Patients with Type 2 Diabetes and Normal Ejection Fraction," *Health*, vol. 7, no. 12, pp. 1721-1724, 2015.

[5] M. K. Poulsen , J.S. Dahl , J. E. Henriksen , T. M. Hey , P.F.Høilund-Carlsen , H. B.Nielsen and J. E. Møller , "Left atrial volume index: relation to long-term clinical outcome in type 2 diabetes," *J Am Coll. Cardiol.*, vol. 62, no. 25, pp. 2416–2421, 2013.

[6] D. P. Guh , W. Zhang, N. Bansback, Z. Amarsi, C. L. Birmingham and A. H. Anis, "The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis", *BMC Public Health*, vol. 9, p.88, 2009.

[7] W. Oliver, G. Matthews, C.R. Ayers, S. Garg, S. Gupta, I.J. Neeland, M.H. Drazner, J.D. Berry, S. Matulevicius and J.A. de Lemos, "Factors associated with left atrial remodeling in the general population," *Circ Cardiovasc Imaging*, vol. 10, pp. e005047, 2017.

[8] M. Tadic, S. Ilic, C. Cuspidi, B. Ivanovic, L. Bukarica, N. Kostic, T. Marjanovic, V. Kocijancic and V. Celic, "Left and right atrial phasic function and deformation in untreated patients with prediabetes and type 2 diabetes mellitus," *Int J Cardiovasc. Imaging*, vol. 31, pp. 65–76, 2015.

[9] American Diabetes Association, "Classification and diagnosis of diabetes: standards of medical care in diabetes-2018," *Diabetes Care*, vol.41, pp. S13–S27,2018.

[10] M. K. Mohammed and S. I. Essa, "Evaluation of the Physical Parameters on Ischemic Heart Disease Patients Using Echocardiography," *Iraqi Journal of Science*, vol. 63, no. 8, pp. 3354-3358, 2022.

[11] S.F. Nagueh , O. A. Smiseth , C. P. Appleton , B.F. Byrd , H. Dokainish , T. Edvardsen , F. A. Flachskampf , T. C. Gillebert , A. L. Klein , P. Lancellotti , P. Marino , J. K. Oh , B. A. Popescu and A. D .Waggoner, "Recommendations for the evaluation of left ventricular diastolic function by echocardiography: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging", *Eur. J. Echocardiogr.*, vol. 17, pp. 1321–1360, 2016.

[12] H.Y. Chiu, P.Y. Chen, L.P. Chuang, N.H. Chen, Y.K. Tu, Y.J. Hsieh, Y.C. Wang and C. Guilleminault, "Diagnostic accuracy of the Berlin questionnaire, STOP-BANG, STOP, and Epworth sleepiness scale in detecting obstructive sleep apnea: a bivariate metaanalysis," *Sleep Med Rev*, vol. 36, pp. 57–70, 2017.

[13] P. Blomstrand , P. Sjöblom , M. Nilsson , M. Wijkman , M. Engvall , T. Länne , F. H. Nyström , C. J. Östgren and J. Engvall ,"Overweight and obesity impair left ventricular systolic function as measured by left ventricular ejection fraction and global longitudinal strain", *Cardiovasc. Diabetol*, vol. 17, pp. 1–12, 2018.

[14] H. Cil , S. Bulur, Y. Türker, A. Kaya, R. Alemdar, A. Karabacak, Y. Aslantaş, I. Ekinözü, S. Albayrak and H. Ozhan," Impact of body mass index on left ventricular diastolic dysfunction," *Echocardiography*, vol. 29, pp. 647–651, 2012.

[15] C. T. Ng. Arnold , F. Prevedello , G. Dolci , C. J Roos , R. Djaberi , M. Bertini , S. Hooi Ewe , C. Allman , D. Y. Leung , N. A. Marsan , V. Delgado and J. J. Bax, "Impact of diabetes and increasing body mass index category on left ventricular systolic and diastolic function," J. *Am. Soc. Echocardiogr*, vol. 31, pp. 916–925, 2018.

[16] J. A. Chirinos , M. Sardana , V. Satija , T. C. Gillebert , M. L. De Buyzere , J. Chahwala , D. De Bacquer , P.Segers and E.R. Rietzschel," Effect of obesity on left atrial strain in persons aged 35–55 years (The Asklepios Study)," *Am. J. Cardiol*, vol. 123, pp. 854–861, 2019.

[17] Yi-C. Wang , C.-Se. Liang , D. M. Gopal , N. Ayalon , C. Donohue , R. Santhanakrishnan , H. Sandhu , A. J. Perez , J. Downing , N.Gokce , W. S. Colucci and E. Ho. Jennifer, "Preclinical systolic and diastolic dysfunctions in metabolically healthy and unhealthy obese individuals," *Circ. Hear. Fail*, vol. 8, pp. 897–904, 2015.

[18] M. R. Movahed and Y.Saito, "Obesity is associated with left atrial enlargement, E/A reversal and left ventricular hypertrophy", *Exp. Clin. Cardiol*, vol. 13, no.2, pp. 89-91, 2008.

[19] H. Taşolar , T. Mete, M. Çetin, B. Altun, M. Ball, A. Bayramoğlu and Y. Ömür Otlu, " Mitral annular plane systolic excursion in the assessment of left ventricular diastolic dysfunction in obese adults," *Anatol. J. Cardiol*, vol. 15, no. 7, pp. 558-564, 2015.

[20] M. M. Barbosa , A. M. Beleigoli, M. de F. Diniz, C. V. Freire, A. L. Ribeiro and M. C. P. Nunes, "Strain imaging in morbid obesity: insights into subclinical ventricular dysfunction," *Clin. Cardiol*, vol. 34, no. 5, pp. 288–293, 2011.

[21] A. D'Andrea , L. Riegler, M. A. Rucco, R. Cocchia, R. Scarafile, G. Salerno, F. Martone, O. Vriz, P. Caso, R. Calabrò, E. Bossone and M. G. Russo, "Left atrial volume index in healthy subjects: clinical and echocardiographic correlates," *Echocardiography*, vol. 30, no. 9, pp. 1001–1007, 2013.

[22] M. Tadic , C. Cuspidi , J. Radojkovic , B. Rihor , V. Kocijanic and V. Celic, "Masked hypertension and left atrial dysfunction: a hidden association," *J. Clin. Hypertens*, vol. 19, pp. 305–311, 2017.

[23] B. D. Powell, M. M. Redfield, K. A. Bybee, W. K. Freeman and C. S. Rihal, "Association of obesity with left ventricular remodeling and diastolic dysfunction in patients without coronary artery disease," *Am. J. Cardiol*, vol. 98, no. 1, pp. 116–120, 2006.

[24] A. Esteghamati , K. Etemad , J. Koohpayehzadeh , M. Abbasi , A. Meysamie , S. Noshad , F. Asgari , M. Mousavizadeh , A. Rafei , E. Khajeh , M. Neishaboury , S. Sheikhbahaei and M. Nakhjavani, "Trends in the prevalence of diabetes and impaired fasting glucose in association with obesity in Iran: 2005–2011," *Diabetes Res. Clin. Pract*, vol. 103, pp. 319–327, 2014.