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ORIGINAL ARTICLE / KLİNİK ÇALIŞMA

Early adulthood obesity is associated with impaired left ventricular and right ventricular functions evaluated by speckle tracking and 3D echocardiography

Erken erişkinlik dönemi obezitesi, 2B benek takibi ve 3B ekokardiyografi ile değerlendirilen bozulmuş sol ve sağ ventrikül fonksiyonları ile ilişkilidir

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ABSTRACT

Objective: The prevalence of obesity is increasing globally. Obesity has been shown to be associated with adverse cardiac outcomes. Current knowledge on the impairment of cardiac function caused by obesity in young adult population is lacking. Therefore, we aimed to evaluate the effect of obesity on cardiac deformation parameters in healthy obese individuals in early adulthood using 2D deformation imaging and 3D echocardiography.
Methods: Seventy-seven volunteers with a body mass index (BMI) above 25 kg/m^2 who were between 18 and 30 years of age and a control group including 40 participants were included. Patients with a history of organic heart disease, poor image quality, or current pregnancy were excluded. Participants were classified as overweight (BMI of 25-29.9 kg/m^2) and obese (BMI $\geq$ 30 kg/m^2). Two dimensional and 3D appropriate echocardiographic images were recorded and further analyzed with a post-processing software to obtain the global longitudinal strain (GLS) of left (LV) and right ventricle (RV).
Results: A total of 117 subjects without metabolic syndrome were enrolled. Conventional dimensional and functional parameters as well as 3D volumetric measurements showed no significant differences among the groups. Presence of epicardial fat tissue was higher in the obese group. Notable differences were found among the groups for both 2D speckle tracking derived and 3D LV GLS, RV GLS, RV free-wall LS (analysis of variance [ANOVA], $p<0.05$) showing lower deformation in obese subjects. LV torsion was found to be significantly higher (ANOVA, $p<0.05$) for the obese group.
Conclusion: Obesity causes subclinical dysfunction of LV and RV in healthy obese subjects in early adulthood. Risk stratification should be performed by considering possible mentioned impact of obesity on myocardial functions.

ÖZET

Amaç: Obezite prevalansı tüm dünyada artmaktadır. Obezitenin olumsuz kardiyak sonuçlarla ilişkili olduğu gösterilmiştir. Genç yetişkin popülasyon için obezitenin neden olduğu kardiyak fonksiyon bozukluğuna ilişkin mevcut bilgiler sınırlıdır. Bu nedenle sağlıklı obez bireylerde erken erişkinlik döneminde obezitenin kardiyak deformasyon parametreleri üzerine etkisini 2B deformasyon görüntüleme ve 3B ekokardiyografi ile değerlendirmeyi amaçladık.
Yöntemler: Vücut kitle indeksi (VKİ) 25 kg/m^2'nin üzerinde ve 18 ile 30 yaşları arasında olan 77 gönüllü çalışmaya alındı. Kontrol grubu olarak 40 kişi dahil edildi. Organik kalp hastalığı öyküsü, kötü görüntü kalitesi veya mevcut hamileliği olan hastalar çalışma dışı bırakıldı. Katılımcılar hafif kilolu (VKİ 25-29.9 kg/m^2) veya obez (VKİ >30 kg/m^2) olarak sınıflandırıldı. 2B ve 3B uygun transtorasik ekokardiyografik görüntüler kaydedildi ve sol (SoV) ve sağ ventrikülün (SaV) global uzunlamasına straini (GUS) elde etmek için uygun yazılımla analiz edildi.
Bulgular: Toplamda metabolik sendromu olmayan 117 gönüllü alındı. Geleneksel boyutsal ve fonksiyonel parametreler ve 3B hacimsel ölçümler gruplar arasında önemli bir farklılık göstermedi. Epikardiyal yağ dokusu varlığı obez grupta daha fazlaydı ($p<0.05$). Hem 2B benek takibi ile elde edilen, hem de 3B SoV GUS, SaV GUS, RV serbest duvar US (ANOVA, $p<0.05$) yönünden, obez grup için daha düşük deformasyon bulunarak anlamlı farklılık saptandı. SoV torsiyonu obezite grubunda anlamlı olarak yüksek bulundu (ANOVA, $p<0.05$).
Sonuç: Obezite,sağlıklı deneklerde erken yetişkinlikte SoV ve SaV'ın subklinik disfonksiyonu ile ilişkilidir. Obezitenin miyokardiyal fonksiyonlar üzerindeki olası söz konusu etkisi dikkate alınarak risk sınıflandırması yapılmalıdır.

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The prevalence of obesity is increasing globally, especially in children and young adults.[1] Obesity has been shown to be associated with heart failure (HF), coronary and peripheral vascular diseases, and to affect the prevalence of complications.[2-8] This relation between obesity and cardiac impairment is mainly the result of increased presence of risk factors, such as hypertension, dyslipidemia, and diabetes. However, good survival rates of obese patients with coronary artery disease and HF have been observed, which led to the introduction of the obesity paradox.[9,10] The current knowledge of the impact of obesity on cardiac dysfunction is based on studies with middle aged and elderly patients, most of whom have metabolic syndrome.[11,12] There are, however, some studies that focused on the impact of obesity on the ventricular function in childhood.[13-15] Nevertheless, current data on the influence of obesity on cardiac function in obese young adults without metabolic syndrome are limited.

Conventional transthoracic echocardiography (TTE) often fails to detect subtle cardiac dysfunction. Deformation imaging and 3D TTE, however, provide additional information on ventricular mechanics with good reproducibility. Thus, subclinical impairment of ventricular function could be assessed with advanced echocardiographic approaches. In this study, we aimed to evaluate the effect of obesity on cardiac deformation parameters in individuals in early adulthood using 2D deformation imaging and 3D TTE.

METHODS

Study population

Among 142 screened volunteers, 117 were prospectively included between December 2019 and June 2020 and followed in Department of Cardiology, Gazi University. Patients with a body mass index (BMI) above 25 kg/m^2 and in their first decade of adulthood (18 to 30 years of age) were included in the study. Forty subjects were enrolled as a control group. Exclusion criteria included having a history of systolic HF, significant valvular pathologies (more than a mild stenosis or insufficiency), pericardial disease, atrial fibrillation, myocarditis, acute myocardial ischemia, active infection, pulmonary embolism, poor image quality for advanced TTE, or being pregnant. Medical records were reviewed for clinical information and laboratory data at the time of TTE. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Systolic blood pressure, diastolic blood pressure, and heart rate were measured using an oscillometric device. Smoking status was assessed by interview. Adult Treatment Panel III criteria were used for metabolic syndrome definition.[16,17] Participants were classified as overweight (BMI of 25-29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2) according to the World Health Organization criteria and compared with the control group (19-24.9 kg/m^2).[18] Participants were informed of the study protocol, and written informed consent was obtained. This study was approved by the Clinical Researches Ethics Committee of Gazi University School of Medicine (Approval Date: December 9, 2019; Approval Number: 233).

Abbreviations:

BMI	*Body mass index*
EF	*Ejection fraction*
FW	*Free wall*
GCS	*Global circumferential strain*
GLS	*Global longitudinal strain*
GRS	*Global radial strain*
HF	*Heart failure*
ICC	*Intra-class correlation coefficients*
LS	*Longitudinal strain*
LV	*Left ventricular*
LVEF	*Left ventricular ejection fraction*
LVMI	*Left ventricular mass index*
ROI	*Region of interest*
RV	*Right ventricular*
SD	*Standard deviation*
STE	*Speckle tracking echocardiography*
TTE	*Transthoracic echocardiography*

Study protocol

Echocardiography

An experienced sonographer performed all the exams with a GE Vivid E95 ultrasound machine equipped with 2D M5Sc-D and 4V-D Probe (GE Vingmed Ultrasound, Horten, Norway). During the TTE, electrocardiogram and respiration monitoring of the patient was performed. Echocardiographic images with at least three cardiac cycles were recorded at the end of expiration. The images were then transferred to a vendor-specific workstation and analyzed with EchoPAC v201 (GE Vingmed Ultrasound, Horten, Norway) software. All echocardiographic measurements were performed according to latest guidelines.[19] Presence of epicardial fat was assessed in parasternal long axis and subcostal views. Left ventricular (LV) chamber dimensions and wall thickness were measured by M-mode. LV mass index (LVMI) was calculated with 3D TTE and indexed to the body surface area. LV ejection fraction (EF) was calculated by both Simpson's biplane method and 3D full volume acquisition. LV and right ventricular (RV) global longitudinal strain (GLS) was measured by speckle tracking echocardiography (STE) and by using 3D LV and RV quantitative analysis. Global circumferential strain (GCS) and global radial strain (GRS) were measured by full volume 3D acquisition and analysis. For 2D STE analysis, end-diastole was defined by positioning the ECG trigger point on peak of the R wave. Time of aortic valve closure and pulmonary valve closure were measured from pulsed wave Doppler acquisitions of LV and RV outflow tract, respectively. Region of interest (ROI) was drawn by defining endocardial and epicardial contours on the respective borders to cover the myocardium. Tracking quality was evaluated by comparing the motion of the tracking points with the motion of the underlying myocardium. LV GLS was calculated as the average of longitudinal strain values obtained from three apical views. To define the ROI on the RV myocardium, the endocardial surface was identified by placing at least 15 markings, starting from the lateral annulus and ending at the septal annulus of the tricuspid valve. RV GLS was measured from all six segments of the RV; whereas for RV free wall (FW), only three lateral segments were used. All strain measurements were performed by S.Ü. who has a long experience in TTE and strain analysis. Three-dimensional imaging was performed with the GE Vivid E95 4V-D Probe (GE Vingmed Ultrasound, Horten, Norway). To ensure that the entire LV was included in the pyramidal scan volume, the wide-angle full-volume mode was used during breath hold in a single expiration. To obtain data sets of appropriate image quality, multi-beat images were recorded consecutively for six beats. The average frame rate for 3D images were 28±3 frames/sec. The acquired ECG-linked images were transferred to the offline EchoPac v201 (GE Vingmed Ultrasound, Horten, Norway) station for analysis. The endocardial border of the LV long axis, including the papillary muscles, was determined by the software. The contours were manually optimized. The software provided dynamic analysis of the cardiac cycle. Finally, torsion values were obtained from GLS time curves using a 17-segment model. Images with poor tracking quality of more than two segments were excluded. For the RV analysis, a modified apical four-chamber view was acquired. Three-dimensional six-beat datasets focused on the RV were obtained during a single expiration and breath hold. Attention was paid to include the entire RV wall surrounding the left ventricle in the form of a crescent. The average frame rate was 23±2 frames/sec. Data was transferred to the offline EchoPac v201 (GE Vingmed Ultrasound, Horten, Norway) for analysis. Six landmark points were manually determined by the guidance of the software to create the ROI. After manual correction of the automatically placed ROI, dynamic cardiac cycle data was provided. The GLS of the RV, longitudinal strain (LS) of the RV FW (RV FW LS), and the interventricular septum were automatically obtained.

Statistical analysis

Normality of distribution was investigated by a Kolmogorov-Smirnov test. Categorical data were presented as percentages, and continuous variables were presented as mean±standard deviation (SD). One-way analysis of variance was used to investigate differences among the groups. Bonferroni analysis was used as post-hoc test. Categorical variables were compared among groups using the χ^2 test. A p value of <0.05 was considered as statistically significant. Intra-observer variability was assessed by intra-class correlation coefficients (ICC) (two-way mixed model, consistency between single measurements). All statistical analyses were performed using the SPSS version 23.0 (IBM Corp.; Armonk, NY, USA).

RESULTS

Of the 142 screened volunteers, 117 were enrolled in the final analysis. None of them had metabolic syndrome. Baseline demographics and clinical characteristics of participants are described in Table 1. These were similar among the groups.

Two dimensional and 3D echocardiographic parameters of LV and RV are shown in Tables 2, 3 and 4, respectively. No differences were observed among the groups for conventional dimensional and functional parameters. Epicardial fat tissue was observed in two (5%), 21 (51%), and 30 (83%) patients enrolled in control, overweight, and obese groups, respectively (p<0.001). In addition, volumetric parameters obtained by 3D TTE were similar among the groups (Tables 2 and 3).

Obese subjects had the least deformation for both ventricles as indicated by notable differences in 2D STE derived LV GLS, RV GLS, and RV FW

Table 1. **Demographic, anthropometric and clinical features of study groups**

Parameters	Control group (n=40)	Overweight (n=41)	Obese (n=36)	*p*
Age	22.9±3.4	24±3.1	23.4±3.5	0.346
Female, n (%)	19 (47.5)	21 (51.1)	17 (47.2)	0.924
BMI (kg/m²)	21.7±2.2	27.3±1.4*	33.4±2.5*†	<0.001
Waist circumference (cm)	79.2±8.5	94.7±16*	98.1±11.7*†	<0.001
BSA (m²)	1.6±0.1	1.9±0.2*	2.1±0.2*†	<0.001
SBP (mmHg)	114.2±15.9	113.3±16.5	118.1±15.2	0.384
DBP (mmHg)	74.3±7.2	75±6.7	74.6±8.6	0.564
Heart rate (bpm)	77±13	79±13	81±11	0.651
Fasting glucose (mg/dL)	86.1±6	88.8±3.9	88.4±6.2	0.053
Triglycerides (mg/dL)	102±28.4	115±20*	140.4±26.9*†	<0.001
HDL (mg/dL)	46.6±8	49.8±8.7	50±9.9	0.170
LDL (mg/dL)	104.5±20.5	113.5±24.8	109.1±18.2	0.163

BSA: body surface area; BMI: body mass index; DBP: diastolic blood pressure; HDL: high density lipoprotein; LDL: low density lipoprotein; SBP: systolic blood pressure.
For post-hoc tests (Bonferroni) of the ANOVA, results are shown as; *significantly different from control group, †significantly different from overweight group.

Table 2. **Echocardiographic measurements of left ventricle and left atrium**

Parameters	Control group (n=40)	Overweight (n=41)	Obese (n=36)	*p*
Dimensions, areas, and volumes of LV and LA				
LV end-diastolic diameter (cm)	4.1±0.6	4.2±0.7	4.4±0.6	0.074
LV end-diastolic volume index (mL/m²)	45.5±10.8	42.1±9.5	44.8±8.6	0.256
3D LV end-diastolic volume index (mL/m²)	52.3±11.9	50.5±13.4	53±10	0.63
LV ejection fraction (%)	65.1±4	64.9±5.6	64.3±4	0.736
3D LV ejection fraction (%)	68.4±7.6	67.1±9.7	67.3±8.4	0.774
3D LV mass index (g)	69.4±21.3	69.7±14.7	70.5±14.4	0.223
LA diameter (cm)	31.6±4.6	31.2±4.6	33.5±5.9	0.497
LA volume index (mL/m²)	21.5±6.4	22.2±6	22.8±4.9	0.645
Doppler measurements of LV				
E (cm/s)	81.5±14.4	84.4±12.5	79.1±14.3	0.247
A (cm/s)	46.3±14.8	50.5±14.5	50.1±16.5	0.402
E/A	1.7±0.4	1.8±0.4	1.7±0.4	0.673
Deceleration time (ms)	178.1±30.4	180.0±28.3	181.1±32.2	0.949
Tissue Doppler measurements of LV				
E’ (cm/s)	15.7±4.3	15.4±4	14.2±3.9	0.221
A’ (cm/s)	8.9±1.6	8.1±2.3	8.2±1.9	0.176
S’ (cm/s)	10±1.6	10.6±2.1	9.9±1.9	0.071
E/E’	5.4±1	5.7±1.3	5.8±1.2	0.220

LA: left atrium; LV: left ventricle.

Table 3. Echocardiographic evaluation of right ventricle and right atrium

Parameters	Control group (n=40)	Overweight (n=41)	Obese (n=36)	*p*
Dimensions, areas, and volumes of RV and RA				
RV basal diameter (cm)	25.4±3.8	26.3±3	26.1±4.4	0.534
RV mid cavity diameter (cm)	23.4±3.2	24.1±3.2	25.1±2.4	0.280
RV longitudinal diameter (cm)	6.9±0.7	6.7±0.6	6.9±0.5	0.079
RV end-diastolic area index (cm^2/m^2)	8.9±2.1	8.2±2.1	7.9±1.5	0.084
RV end-systolic area index (cm^2/m^2)	4.7±1.2	4.2±1.1	4.1±0.8	0.058
RV FAC (%)	47.3±7.5	48.9±5.4	47.5±5.2	0.577
TAPSE (mm)	23.8±3.9	24.5±3	23.8±2.6	0.457
RA longitudinal axis (cm)	3.3±0.3	3.1±0.7	3.4±0.4	0.301
RA short axis (cm)	2.0±0.3	1.9±0.3	2.0±0.3	0.675
RA end-systolic area (cm^2)	15.3±3.1	16.3±3	15.6±3.6	0.412
3D RV end-diastolic volume (mL/m^2)	61.8±8.9	61.6±9.1	65.7±9.8	0.080
3D RV end-systolic volume (mL/m^2)	26.2±5.5	25.6±4.7	27.8±4.8	0.134
3D RV ejection fraction (%)	57.4±6.1	58.5±4.6	57.7±4.4	0.624
Doppler measurements of RV				
E (cm/s)	56.4±9	54.7±9.2	53.9±8.8	0.451
A (cm/s)	38.1±9.2	39.2±8.6	37±7.6	0.536
E/A	1.6±0.4	1.5±0.5	1.5±0.5	0.667
Deceleration time (ms)	173.1±28.5	178.9±28.4	172.1±33.1	0.543
Tissue Doppler measurements of RV				
E' (cm/s)	14.6±3.7	14.1±3.2	13.9±3.4	0.365
A' (cm/s)	15.9.4±14.2	14.2±5.7	14.8±4.9	0.547
S' (cm/s)	13.5±2.6	14.5±2.1	14.1±2.3	0.118

FAC: fractional area change; RA: right atrium; RV: right ventricle; TAPSE: tricuspid annular plane systolic excursion.

Table 4. Left and right ventricular deformation analysis results with 2D speckle tracking echocardiography

Parameters	Control group (n=40)	Overweight (n=41)	Obese (n=36)	*p*
2D LV GLS (%)	-22.6±3.3	-21.3±3.3	-19.6±2.9*†	<0.001
2D RV GLS (%)	-26.2±5.5	-25.3±4	-21.9±3.2*†	<0.001
2D RV free wall LS (%)	-28.4±5.1	-25.4±4.4	-22.4±3.9*†	<0.001

GLS: global longitudinal strain; LS: longitudinal strain; LV: left ventricle; RV: right ventricle.
For post-hoc tests (Bonferroni) of the ANOVA, results are shown as; *significantly different from control group, †significantly different from overweight group.

LS (Table 4). Similar findings regarding longitudinal deformation parameters were obtained by 3D TTE (Figure 1). LV torsion was found to be significantly higher in the obese group (Figure 1B). Three dimensional GCS and GRS values are presented in Supplementary Figure 1.

Intra-observer reproducibility

Among the conventional echocardiographic parameters, LV EF, tricuspid annular plane systolic excursion, and S' velocity of lateral annulus of RV showed very good reproducibility (intra-class correlation coefficient [ICC]: 0.873, 95% confidence interval

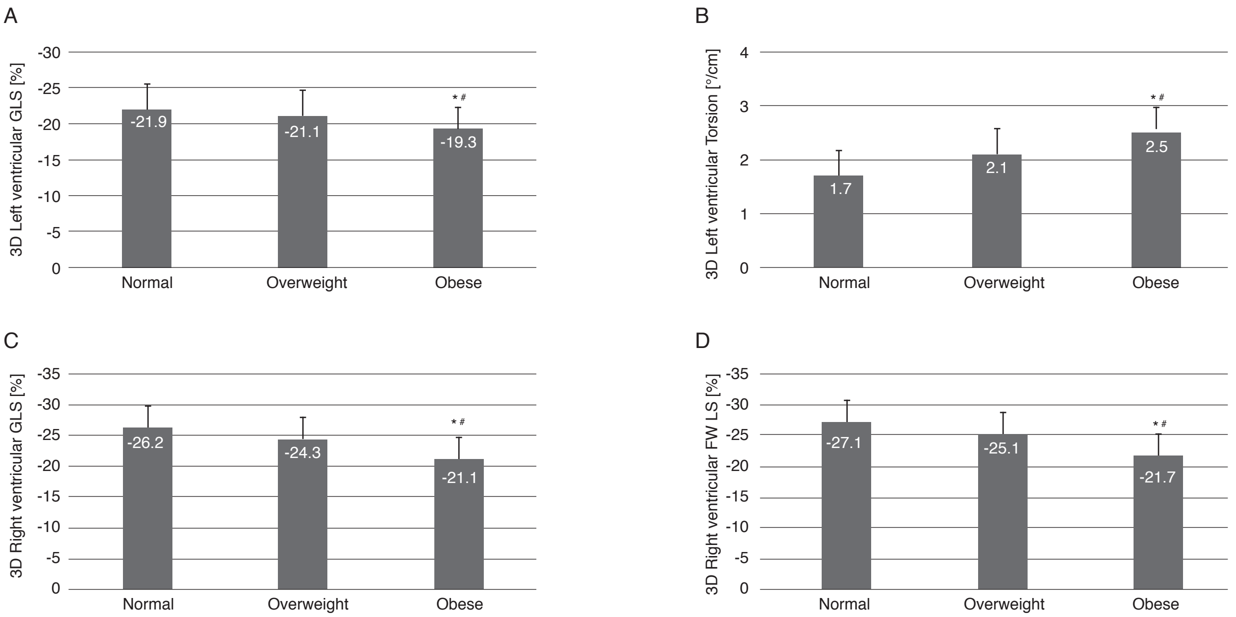

Figure 1. (A) Average 3D left ventricular global longitudinal strain (GLS) with standard deviations. **(B)** Average 3D left ventricular torsion with standard deviations. **(C)** Average 3D right ventricular GLS strain with standard deviations. **(D)** Average 3D right ventricular free-wall longitudinal strain with standard deviations for control, overweight, and obese groups. For post-hoc tests (Bonferroni) analysis of variance results are shown as; *significantly different from control group, #significantly different from overweight group.

[CI]: 0.758-0.960 and ICC: 0.878, 95% CI: 0.782-0.950, respectively). Intra-observer variability of 2D STE derived RV and LV GLS and 3D LV torsion also showed good reproducibility (ICC: 0.840, 95% CI: 0.776-0.960; ICC: 0.838, 95% CI: 0.732-0.930; and ICC: 0.820, 95% CI: 0.711-0.919, respectively).

DISCUSSION

In this study, we investigated the impact of obesity on deformation parameters obtained by 2D STE and 3D TTE. The main findings can be summarized as follows:

Conventional echocardiographic parameters did not show significant difference among the groups.

LV GLS, RV GLS, and RV FW LS are significantly lower in obese patients.

LV torsion assessed by 3D TTE is found to be higher in obese patients.

Obesity is shown to have an impact on cardiac structure and function.[7,11,14,20–23] The increase in LV mass and diameters of LV and left atrium and the presence of epicardial fat are frequently observed findings.[11,14,20,22-24] Moreover, childhood, adolescent, or early adulthood obesity was found to be associated with subclinical atherosclerosis as obesity causes endothelial dysfunction and thickening of the intima media as well as increased arterial stiffness. These findings could be related to high blood pressure, abnormal fasting lipid profiles, and inflammation. Furthermore, it has been shown that obesity during childhood is associated with the development of adulthood cardiovascular diseases despite weight reduction.[13-15,25-29] An important independent relation between obesity and especially HF with preserved ejection fraction exists. Even the metabolically “healthy” obese patients who have relatively normal levels of fasting plasma glucose and lipids as well as normal levels of blood pressure, were found to be at increased risk for cardiovascular adverse events.[30] Adipose tissue has been shown to be very active as it secretes various pro-inflammatory neurokines/cytokines, including IL-1, TNF-alpha, IL-6, and monocyte chemotactic protein-1. These molecules have a direct impact on myocardial morphology.[31] Beyond atherosclerosis development, lipotoxicity owing to intracellular lipid accumulation can induce alterations in cardiac structure and function.[11,14,20,22]

Epicardial fat tissue has also been shown to be metabolically active and associated with increased cardiometabolic risk. We found an increased prevalence in the patients with obesity. Duration of obesity could be also an important determinant of impaired cardiac functions; however, it was not possible to exactly determine the actual duration from the medical history of the patients.

Assessment of LV function

Conventional echocardiographic parameters were similar among groups. Previous studies performed in adults showed that LV mass index was increased even in healthy obese patients.[22,30] However, in our study, LV mass index did not show any significant difference in obese patients compared with the control group.

Two-dimensional STE and 3D TTE provided indices that elucidated subclinical abnormalities in myocardial function in patients with obesity. Our study confirms similar findings of reduced longitudinal deformation in young adults with obesity. GLS provides additional information on the left ventricular ejection fraction (LVEF) for detection of subtle dysfunction of the myocardium, which would help in predicting HF development. GLS has proven to be a superior prognostic marker of cardiac function for various diseases, especially in patients with preserved LVEF.[32,33] In this study, we found that LV GLS is impaired even in metabolically healthy, obese, young individuals compared with control subjects. Furthermore, it has been reported that obesity is associated with LV diastolic dysfunction.[11,22,34] However, in our study, we observed no significant differences regarding diastolic dysfunction. The younger overall age of our study population could probably explain this discrepancy. Overall, our findings suggest that patients with good metabolic status might not be protected from adverse cardiac events as subtle impairment of LV function is already present. These results indicate that obesity may lead to adverse cardiovascular events regardless of metabolic disease.

LV base twists in the opposite direction to the apex whereas torsion is the amount of twist difference for LV length. Spiral myofiber architecture and various orientation of the fibers causes the mentioned pattern of net LV twist and torsion. Three dimensional TTE eases calculation of torsion as a pyramidal full volume of the LV and can be analyzed at once. We found that LV torsion is higher for obese patients, which could be explained by the LV compensating for the reduction in longitudinal deformation by increasing the twist.

Assessment of RV functions

Obesity has been shown to affect RV function and cause RV remodeling, mainly because of breathing disorders and increased post-capillary pressure,[35] although inflammation and lipotoxicity could play a role as well. Conventional TTE often fails to provide a robust and reproducible parameter for the assessment of the RV owing to its crescentic shape and anatomical location. However, developments in deformation imaging and especially 3D TTE provides new solutions for the evaluation of RV function. It has been shown that adults with obesity have larger RV dimensions and higher mass compared with normal subjects.[35] However, data regarding young adults is lacking. In our study, we found that RV deformation is impaired in obese patients compared with the overweight and control groups. Our findings support the fact that obesity has an adverse impact on both LV and RV functions.

Limitations

We performed a cross sectional study without follow-up, thus we could not determine how adverse myocardial changes caused by obesity would affect clinical outcome. Larger longitudinal studies are needed to examine the impact of obesity on myocardial function and how modification of obesity can affect outcome. Despite significant differences in deformation parameters among the study groups, we have found that the mean of GLS values of obesity and overweight groups are still in normal ranges. As mentioned before, we do not have follow-up data of the study population, which would have provided more important clinical information.

BMI was used to define groups and degree of obesity. Other measures such as body fat percentage or distribution of body fat would have provided a more thorough understanding of the relationship between impaired myocardial function and obesity.

Echocardiographic examination of obese patients can be challenging; however, with the recent technological improvement of ultrasound devices and probes, images with better quality can be obtained.

Multi-beat acquisition and proper positioning of the patients are critical steps for obtaining a satisfactory image dataset with 3D TTE.

Conclusion

Obesity was associated with subclinical LV and RV dysfunction, reflected by lower myocardial deformation, even in obese subjects in early adulthood and without metabolic syndrome. Possible impairment of myocardial function because of obesity should be considered in the risk stratification of young individuals.

Ethics Committee Approval: Ethics committee approval was received for this study from the Clinical Researches Ethics Committee of Gazi University School of Medicine (Approval Date: December 9, 2019; Approval Number: 233).

Peer-review: Externally peer-reviewed.

Authorship contributions: Concept - S.Ü.; Design - S.Ü., G.T.; Supervision - G.T.; Materials - S.Ü., G.T; Data - S.Ü.; Analysis - S.Ü.; Literature search - S.Ü; Writing - S.Ü.; Critical revision - G.T.

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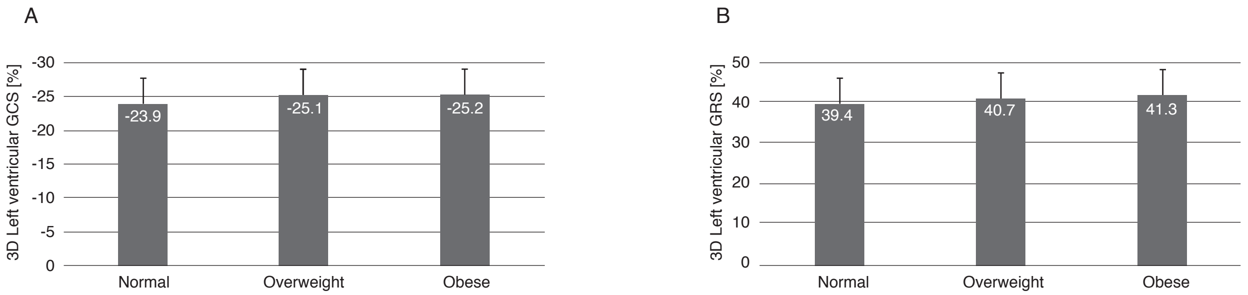
Anahtar Kelimeler: Obezite; kardiyovasküler risk faktörleri; ekokardiyografi; üç boyutlu



Supplementary Figure 1. (A) Average 3D left ventricular global circumferential strain with standard deviations (analysis of variance [ANOVA], p=0.315). **(B)** Average 3D left ventricular global radial strain with standard deviations (ANOVA, p=0.298).