The utility of heart rate recovery to predict right ventricular systolic dysfunction in patients with obesity

Obezlerde sağ ventrikül sistolik disfonksiyonunun saptanmasında egzersiz sonrası kalp hızı toparlanmasının değeri

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ABSTRACT

Objective: Obesity is a nutritional disorder, which is associated with impaired left and right ventricular function. Impaired heart rate recovery (HRR) following a treadmill exercise test is an indicator of cardiovascular mortality. We investigated the utility of impaired HRR on the tissue Doppler imaging (TDI) echocardiographic estimates of left and right ventricular function in an obese/overweight cohort.
Methods: Eighty consecutive patients with body mass index >27 kg/m^2 were evaluated for their post exercise HRR in this cross-sectional study. The results were compared with the tissue Doppler and conventional echocardiographic findings of the same cohort. Tricuspid annular TDI peak systolic velocities (RVs) were evaluated with receiver operating characteristic (ROC) analysis to predict the insufficient heart rate recovery (18/min or less). Logistic regression analysis was used to identify the independent predictors of significant right ventricular systolic dysfunction (RVs <10 cm/sec) among the clinical and echocardiographic parameters.
Results: There was a positive correlation between HRR and tricuspid annulus peak systolic velocity, exercise distance, and METs. The patients with impaired HRR at post-exercise first minute had lower exercise distance (p<0.0001), METs (p=0.001), RVs (p=0.037), and basal septal peak systolic velocity (p=0.041) than the patients with normal HRR. A tricuspid annulus TDI peak systolic velocity of 10 cm/sec predicted post-exercise preserved HRR with 70% sensitivity and 55% specificity with ROC analysis (AUC=0.638, 95% CI- 0.509-0.767, p=0.037). The subjects with tricuspid annulus peak systolic velocity (RVs) <10cm/sec were found to have larger body mass indices, impaired post-exercise first minute HRR, shorter total exercise distance, and lower total METs than the subjects with tricuspid annulus peak systolic velocity >10cm/sec. Impaired HRR and septum TDI late diastolic velocity were found as the independent predictors of right ventricular systolic function (RVs<10cm/sec) by logistic regression analysis.
Conclusion: Post-exercise first minute impaired HRR is associated with right ventricular systolic dysfunction in obese patients. Both HRR and right ventricular systolic function correlate well with the exercise distance and METs. Obese patients with impaired HRR should be evaluated with echocardiography to assess their right ventricular systolic function. *(Anadolu Kardiyol Derg 2009; 9: 473-9)*
Key words: Heart rate recovery, heart failure, obesity, tissue Doppler echocardiography, predictive value of tests

ÖZET

Amaç: Obezite hem sol, hem de sağ ventrikül fonksiyonları üzerine olumsuz etkileri olan beslenme bozukluğudur. Egzersiz testi sonrasında yetersiz kalp hızı toparlanması kardiyovasküler mortalitenin bir belirteçi olarak bulunmuştur. Çalışmamızda, obezlerde yetersiz kalp hızı toparlanmasının sol ve sağ ventrikül fonksiyonları üzerine etkisi doku Doppler görüntülemesi (TDI) yöntemi ile incelendi.
Yöntemler: Vücut kitle indeksi >27 kg/m^2 olan 80 hasta prospektif olarak enine-kesitli çalışmaya dahil edildi ve egzersiz stres testi sonrası kalp hızı toparlanmaları incelendi. Bulgular aynı grubun doku Doppler ve konvansiyonel ekokardiyografik inceleme kayıtlarıyla karşılaştırıldı. Triküspid anulus pik sistolik hızının bozulmuş kalp hızı toparlanmasını (18/dak veya daha az) öngörmedeki kestirim değeri ve yeterliliği ROC analizi ile araştırıldı. Belirgin sağ ventrikül sistolik disfonksiyonunun (RVs<10cm/sn) bağımsız belirleyicileri lojistik regresyon analizi ile incelendi.
Bulgular: Kalp hızı toparlanması ile triküspid anulus pik sistolik hızı, egzersiz mesafesi ve METs arasında pozitif korelasyon saptandı. Egzersiz sonrası 1. dakikada kalp hızı toparlanması bozulmuş olan hastalarda egzersiz mesafesi (p<0.0001), METs (p=0.001), RVs (p=0.037) ve bazal septum TDI pik sistolik hızı (p=0.041) anlamlı olarak düşük saptandı. ROC analizinde triküspid anulus TDI pik sistolik hızının 10cm/sn'nin üzerinde olması, egzersiz sonrası korunmuş kalp hızı toparlanmasını %70 duyarlılıkla ve %55 özgüllük belirledi (EAA=0.638, %95GA - 0.509-0.767, p=0.037).

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Triküspid anulus peak sistolik hızı (RVs) 10cm/sn'nin altında olan alt grupta vücut kitle indeksi yüksek, egzersiz sonrası 1. dakika kalp hızı toparlanması bozulmuş, yürüme mesafesi ve METs değerleri ise düşük saptandı. Lojistik regresyon analizinde bozulmuş kalp hızı toparlanması ve septum TDI geç diyastolik hızı belirgin sağ ventrikül sistolik disfonksiyonunun (RVs<10cm/sn) bağımsız belirteçleri olarak bulundu.

Sonuç: Obezlerde egzersiz sonrası 1. dakikadaki yetersiz kalp hızı toparlanması sağ ventrikül sistolik disfonksiyonu ile ilişkilidir. Kalp hızı toparlanması ve sağ ventrikül sistolik fonksiyonları egzersiz mesafesi ve METS ile korelasyon göstermektedir. Egzersiz testinde bozulmuş kalp hızı toparlanması saptanan obez hastalar sağ ventrikül fonksiyonları değerlendirilmesi amacıyla ekokardiyografik incelemeye yönlendirilmelidir.

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Anahtar kelimeler: Kalp hızı toparlanması, kalp yetersizliği, obezite, doku Doppler ekokardiyografi, testlerin öngörme değerleri

Introduction

Obesity is one of the most common nutritional disorders in developed countries. It is associated with significant cardiovascular morbidity and mortality (1). In addition, it increases the risk of congestive heart failure (2). The negative impact of obesity on the left and right ventricular systolic function has been reported previously (3-9). Tissue Doppler imaging (TDI) assessment of myocardial velocities is useful for quantitative assessment of myocardial systolic and diastolic functions (4-7, 9-13). On the other hand, heart rate recovery (HRR) following a treadmill-exercise test is an independent predictor of all-cause cardiovascular mortality in the adult population (13-19). Heart rate recovery is a reflection of vagal reactivation; therefore impaired HRR is considered to represent decreased vagal tone (20-22). Impaired HRR is common in people with obesity or metabolic syndrome and it usually recovers with weight loss (23, 24). However, there is limited information about the association between impaired HRR and myocardial functions.

In our study, we investigated the possible association between HRR and tissue Doppler estimates of the left and right ventricular function in an overweight/obese population.

Methods

Eighty consecutive overweight (body mass index [BMI]>27 kg/m^2) patients with sinus rhythm who have been referred for a treadmill exercise test were prospectively recruited. The reason for exercise test request was atypical chest discomfort in 56 patients, exercise induced dyspnea in 18 patients, and routine cardiologic check-up in 6 patients. Patients with history of coronary artery disease, evidence of coronary artery disease on exercise stress test (positive exercise test) or echocardiography (segmental wall motion abnormality), heart failure, chronic respiratory disease that may cause right ventricular dysfunction, valvular heart disease, chronic renal failure, orthopedical or musculoskeletal disorder, poor echocardiographic image quality were excluded. This cross-sectional study was approved by institutional review board, and all patients gave written informed consent to participate in the study.

Treadmill exercise test protocol

All patients underwent symptom limited exercise test with standard Bruce protocol (Kardiosis ARS Treadmill, Kardiosis Ltd, İstanbul, Turkey). Beta-blockers and nondihydropyridine calcium antagonists were stopped one week prior to the exercise stress test. The 12-lead electrocardiograms were obtained at the resting phase of the test. Functional capacity was measured in metabolic equivalents (METs, where one MET is 3.5 mL/kg per min of oxygen consumption) on the basis of a previously published nomogram (25). Blood pressure recordings were obtained at the end of each stage with an arm-cuff sphygmomanometer. The test was stopped upon either symptom development (dyspnea, fatigue, or leg pain) or achievement of the target heart rate. Heart rate recovery was defined as the difference between heart rate at peak exercise and one minute later. A cut-off value of 18/min or less was considered abnormal based on a previous study from Watanabe and coworkers (26). Patients were subgrouped into two groups according to the HRR: Group 1 - HRR less than 18/min at the first minute (n=34) and Group 2 - HRR greater than 18/min at the first minute (n=46).

Echocardiographic assessment

Echocardiography was performed on all patients in the left lateral decubitus position from the standard views using commercially available equipment (Vivid 5, GE Vingmed, Horten, Norway). Left atrial systolic dimension and LV internal dimensions and wall thickness were measured from 2-dimensional guided M-mode echocardiographic tracings obtained at midchordal level in the parasternal long-axis view according to American Society of Echocardiography criteria (27). Left ventricular mass was calculated according to the previously described method of Devereux et al. (28), and normalized to height in meters. Percent fractional shortening and ejection fraction were calculated using the Teichholz Formula (29). Mitral inflow velocities were obtained by pulsed wave Doppler in the apical 4-chamber view with the sample volume placed at the tips of the mitral valve leaflets. The peak early (E) and late (A) diastolic mitral inflow velocities, deceleration time E, E/A ratio and isovolumetric relaxation time were measured and averaged over 3 cardiac cycles according to the recommendations of the American Society of Echocardiography (30). Color tissue Doppler imaging was performed from the apical 4-chamber view using a 2.5-MHz transducer and frame rates of >80/sec and the images were digitized. Derivation and analysis of tissue Doppler velocity profiles were performed offline using commercially available computer software (Echopac 6.4 Vingmed, Horten, Norway). Myocardial velocity profiles of the basal septal and lateral mitral annulus were obtained by placing a 6-mm sample volume at the junction of the mitral annulus with septum and lateral myocardial wall. Myocardial velocities of the lateral tricuspid annulus were obtained similarly by placing the sample volume at the junction of the tricuspid valve annulus and right ventricular free wall. Peak septal and lateral mitral annular systolic, early diastolic, and late diastolic velocities were measured from 3 consecutive cardiac cycles and averaged. The ratio of peak early diastolic mitral inflow velocity by pulse-wave Doppler and peak early diastolic mitral annular velocity by tissue Doppler imaging, a measure of LV filling pressure, was calculated (31). Peak tricuspid annular systolic, early diastolic, and late diastolic velocities were also measured from 3 consecutive cardiac cycles and averaged.

Statistical analyses

SPSS for Windows Version 15 (SPSS Inc, Chicago, Illinois, USA) commercially available software was used for statistical analysis. Descriptive statistics are shown as mean ± SD. Parameters normally distributed were compared with the unpaired Student's t-test. The Mann-Whitney U test was applied to asymmetrically distributed data. Fisher Exact (Chi-square) test was used for comparison of categorical variables. Pearson's correlation coefficients were used to assess the association between anthropometric measures, echocardiographic data, and exercise test parameters. Tricuspid annular TDI peak systolic velocities (RVs) were evaluated by ROC analysis in predicting the insufficient heart rate recovery. In order to determine the optimal RVs values to predict impaired heart rate recovery (18/min or less), the closest value to the best specificity and sensitivity point on the ROC curve was identified. Logistic regression analysis was performed to evaluate the independent predictors of impaired HRR. Post-exercise impaired HRR (18/min or less) was determined as dependent variable and BMI, basal heart rate, METs, septum TDI peak systolic velocity, and RVs were independent parameters in the model. Logistic regression analysis was also used to identify the independent predictors of significant right ventricular systolic dysfunction (RVs <10 cm/sec) among the clinical and echocardiographic parameters: RVs <10 cm/sec was determined as dependent variable and BMI, presence of impaired HRR (HRR<18/min), left ventricular end-systolic and end-diastolic dimensions, left ventricular ejection fraction, E/A ratio, septum TDI peak systolic, early and late diastolic velocities, and E/e' ratio were independent parameters in the model. A p value <0.05 was accepted as significant for all statistics.

Results

The study population included 58 women (72.5%) and 22 men (27.5%). The mean age of study population was 51±8 years and mean BMI was 34±5. Thirty-three patients had history of type 2 diabetes (41%) and 49 patients had hypertension (61%). Table 1 demonstrates the clinical characteristics of patients in Group 1 and 2. Group 1 subjects were heavier (p=0.038), had a larger waist circumference (p=0.038) and an increased BMI (p=0.044) than Group 2. The patients with impaired HRR at first minute had higher resting, post-exercise first, and post exercise third minute heart rate (p=0.008, p=0.001 and p=0.045, respectively). Their exercise distance and METS were less than the patients with normal HRR (p<0.0001 and p=0.001 respectively) (Fig. 1). Conventional echocardiographic parameters between Group 1 and Group 2 were similar. Group 1 patients had lower RVs (p=0.037) and basal septal peak systolic velocity (p=0.041) than Group 2.

Predictors of impaired HRR in obese patients

Logistic regression analysis revealed that METs (OR=16.7, 95% CI-1.25-2.87, p<0.0001), basal heart rate (OR=7.6, 95% CI-0.92-1.0, p=0.006), and RVs (OR=3.3, 95% CI-0.65-1.7, p=0.047) were the independent predictors of impaired HRR. ROC analysis was performed to assess the utility of RVs to predict post-exercise first minute impaired HRR. A tricuspid annulus TDI peak systolic velocity of 10 cm/sec predicted postexercise preserved HRR with 70% sensitivity and 55% specificity (AUC=0.638, 95% CI-0.509-0.767, p=0.037) (Fig. 2).

Predictors of right ventricular systolic dysfunction in obese patients

When the patients were reevaluated according to this cut-off levels, patients with RVs less than 10 cm/sec were found to achieve lower METS (p<0.0001) and have higher BMIs (p=0.05) compared to the patients with velocities higher than 10 cm/sec (Fig. 3) Their postexercise HRR was also impaired as well. Both groups were similar in conventional echocardiographic parameters. Table 2 refers to the conventional and TDI derived echocardiographic parameters between patients with RVs less or greater than 10 cm/sec. Logistic regression analysis revealed that impaired HRR (OR=4.5, 95% CI-1.29-16.1, p=0.018) and septum TDI late diastolic velocity (OR=1.9, 95% CI-1.15-3.14, p=0.012) were the independent predictors of significant RV systolic dysfunction.

Discussion

Our study demonstrated a significant correlation between

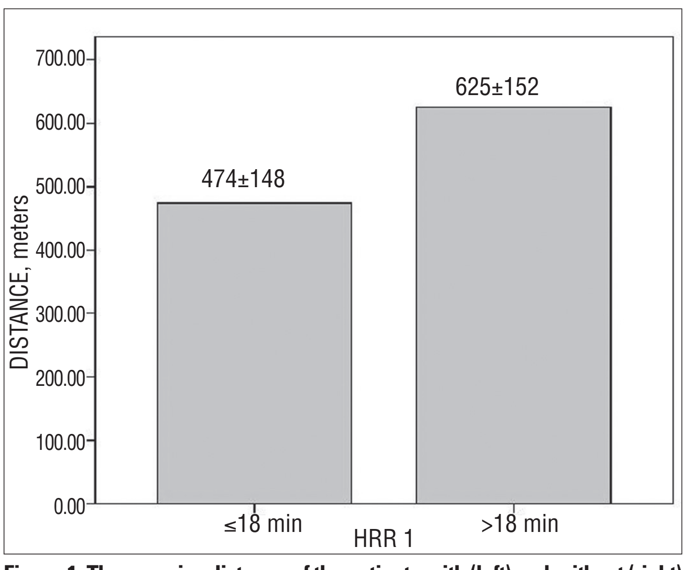

Figure 1. The exercise distance of the patients with (left) and without (right) impaired heart rate recovery (HRR)

Table 1. Clinical, demographic and echocardiographic characteristics of the patients with impaired and preserved heart rate recovery

	Group 1 (n=34)			Group 2 (n=46)			p**
Parameters	**Mean**	**Median**	**Min-Max**	**Mean**	**Median**	**Min-Max**	
Gender, F\M, n*	24/10			34/12			NS
Age, years	50±9	50.0	34-74	51±8	50.5	34-72	NS
HT, +/-, n*	20/14			29/17			NS
DM, +/-, n*	14/20			19/27			NS
BMI, kg/m^2	35.4±4.0	36.7	27.9-47.2	33.5±5.0	32.2	20.9-53.8	0.044
Basal Heart Rate, bpm	91±14	94	58-120	82±16	81	50-121	0.008
Maximal Heart Rate, bpm	155±13	155	132-190	161±17	158	130-203	NS
HRR 1, bpm	12±4	13	4-18	31±12	28	20-56	<0.0001
METs, unit	9.2±1.7	9.7	6.9-13	11.0±1.9	10.9	7-14.8	0.001
Distance, m	474±148	440	207-728	625±152	652	226-947	<0.0001
LA, cm	3.4±0.4	3.4	2.5-4.3	3.5±0.5	3.5	2.6-4.4	NS
Ao, cm	2.6±0.4	2.7	1.8-3.9	2.6±0.5	2.5	1.8-3.9	NS
LVEDD, cm	4.9±0.5	5.0	4.1-6.2	4.9±0.5	4.9	3.7-6.3	NS
LVESD, cm	3.0±0.5	2.9	2.1-4.1	3.0±0.5	2.9	2.1-4.5	NS
IVS, cm	1.25±0.20	1.27	0.8-1.6	1.27±0.20	1.26	0.9-1.7	NS
PW, cm	1.10±0.20	1.11	0.9-1.5	1.12±0.20	1.10	0.7-1.8	NS
LVEF, %	70.0±6.9	71	57-85	70.0±6.7	70	55-80	NS
LVM, g/m^2	147±50	138	78-322	148±46	141	78-321	NS
Mitral E vel., m/sec	0.70±0.10	0.68	0.47-1.00	0.69±0.10	0.66	0.42-1.00	NS
Mitral A vel., m/sec	0.79±0.20	0.79	0.45-1.20	0.76±0.10	0.75	0.52-1.20	NS
E/A ratio	0.93±0.30	0.81	0.56-1.70	0.92±0.20	0.85	0.59-1.60	NS
dtE, msec	274±99	254	138-630	274±88	252	167-540	NS
IVRT, msec	111±22	110	67-147	122±27	123	58-182	NS
RVs, cm/sec	10.2±1.4	9.8	8.5-12.8	10.9±1.5	11	6.8-13.9	0.037
RVe, cm/sec	7.1±2.3	7.2	2.8-11.8	7.3±2.2	7.5	3.1-12.3	NS
RVa, cm/sec	10.7±2.5	11.2	4.7-14.4	10.3±2.8	9.9	4.4-16.6	NS
SEPs, cm/sec	6.5±1.2	6.5	2.6-8.4	6.0±1.1	6.0	4.0-9.3	0.041
SEPe, cm/sec	5.4±2.2	5.2	1.6-11.7	5.0±1.4	4.9	2.0-8.3	NS
SEPa, cm/sec	8.2±1.7	8.1	3.2-13.7	7.9±1.7	7.8	3.9-13	NS
LATs, cm/sec	7.0±1.9	6.9	3.4-10.6	6.9±1.6	6.6	4.2-10.3	NS
LATe, cm/sec	7.2±3.1	7.5	1.6-14.6	7.2±2.6	6.9	2.8-13.3	NS
LATa, cm/sec	8.6±2.2	8.6	4.1-14.9	8.6±1.9	8.5	4.5-13.7	NS
E/e ratio	15.2±9.0	12.4	5.6-51.8	14.9±6.0	13.1	9.3-42.3	NS

Data are presented as mean±SD, median (minimum-maximum) values and *proportions
** - unpaired Student's t, Mann-Whitney U and Pearson Chi-square tests
Ao - aorta, BMI - body mass index, dtE - E wave deceleration time, HRR 1 - heart rate recovery at 1st minute, IVRT - isovolumic relaxation time, IVS - interventricular septum, LA - left atrium, LATs - lateral mitral annular systolic velocity, LATe - lateral mitral annular early diastolic velocity, LATa - lateral mitral annular late diastolic velocity, LVEDD - left ventricular end-diastolic diameter, LVEF - left ventricular ejection fraction, LVESD - left ventricular end-systolic diameter, LVM - left ventricular mass, METs - metabolic equivalent unit, PW - posterior wall, RV - right ventricle, RVs - lateral tricuspid annular systolic velocity, RVe - lateral tricuspid annular early diastolic velocity, RVa - lateral tricuspid annular late diastolic velocity, SEPs - septal annular systolic velocity, SEPe - septal annular early diastolic velocity, SEPa - septal annular late diastolic velocity

HRR and right ventricular tissue Doppler parameters among the obese people. We found out that the patients with impaired HRR had larger BMI and lower functional capacities than the patients with normal HRR.

Right ventricular dysfunction was common in patients with impaired HRR. Many studies reported the association of impaired HRR following exercise with the all-cause and cardiac mortality (14-16, 18, 26, 32, 33). Impaired HRR is frequently present in people with obesity or metabolic syndrome and it usually recovers after weight loss (23, 24). The studies on right ventricular function in obesity have revealed conflicting results. Otto and coworkers reported that right ventricular relaxation and filling

Table 2. Clinical, demographic and echocardiographic characteristics of the patients with RVs below and above 10 cm/sec

	RVs < 10 cm/sec (n=32)			RVs > 10 cm/sec (n=48)			p**
Parameters	Mean	Median	Min-Max	Mean	Median	Min-Max	
Gender, F\M, n*	25/7			33/15			NS
Age, years	50±9	51	34-64	51±8	50	34-74	NS
BMI, kg/m²	34.9±5	36.7	20.9-42.9	33.8±5	32.3	25.4-53.8	0.05
Basal Heart Rate, bpm	87±15	87	58-117	85±16	84	50-121	NS
Maximal Heart Rate, bpm	159±14	156	136-190	159±17	155	130-203	NS
HRR 1, bpm	14±12	17	4-54	25±13	24	4-56	0.047
METs, unit	8.8±1.2	9.2	6.9-10.0	11.0±1.8	10	6.9-14.8	<0.0001
Distance, m	457±143	446	207-705	623±149	646	350-947	<0.0001
LA, cm	3.4±0.4	3.4	2.5-4.4	3.5±0.4	3.5	2.6-4.3	NS
Ao, cm	2.6±0.5	2.6	1.8-3.9	2.6±0.5	2.6	1.8-3.9	NS
LVEDD, cm	5.0±0.5	5.0	3.7-6.2	4.9±0.5	4.9	4.1-6.3	NS
LVESD, cm	3.1±0.5	3.1	2.2-4.1	3.0±0.5	2.9	2.1-4.5	NS
IVS, cm	1.23±0.20	1.2	0.9-1.5	1.28±0.20	1.3	0.8-1.7	NS
PW, cm	1.13±0.20	1.2	0.7-1.5	1.10±0.20	1.1	0.9-1.8	NS
LVEF, %	68±6	68	57-85	71±6	73	55-82	NS
LVM, g/m²	148±41	138	82-267	148±51	145	78-322	NS
Mitral E vel., m/sec	0.69±0.13	0.67	0.47-0.99	0.68±0.13	0.67	0.42-1.0	NS
Mitral A vel., m/sec	0.80±0.19	0.79	0.50-1.2	0.76±0.16	0.74	0.45-1.2	NS
E/A ratio	0.90±0.20	0.82	0.56-1.65	0.93±0.20	0.85	0.58-1.70	NS
dtE, msec	297±112	266	138-630	271±78	248	169-540	NS
IVRT, msec	121±23	120	67-164	114±27	110	58-182	NS
RVs, cm/sec	9.1±0.6	9.2	6.8-9.9	11.6±1	11.6	10-13.9	<0.0001
RVe, cm/sec	6.8±2.3	6.3	3.1-11.0	7.5±2.1	7.6	2.8-12.3	NS
RVa, cm/sec	10.1±2.5	10.8	4.4-14.2	10.7±2.8	10.4	5.5-16.6	NS
SEPs, cm/sec	5.8±1.3	5.5	2.6-8.4	6.5±1	6.5	4.1-9.3	0.014
SEPe, cm/sec	4.9±1.8	4.7	1.6-9.1	5.3±1.7	5.1	2.1-11.7	NS
SEPa, cm/sec	7.3±1.5	7.5	3.2-9.5	8.5±1.7	8.1	5.9-13.7	0.010
LATs, cm/sec	6.6±1.8	6.3	3.4-10.2	7.2±1.6	6.9	4.4-10.6	NS
LATe, cm/sec	6.7±2.7	6.9	1.6-11.6	7.6±2.9	7.2	1.8-14.6	NS
LATa, cm/sec	8.4±2.2	8.2	4.1-13.3	8.8±2.0	8.7	5.3-14.9	NS
E/e ratio	16.5±9.0	15.1	5.6-51.8	14.2±6.0	13.3	7.8-42.3	NS

Data are presented as mean±SD, median (minimum-maximum) values and *proportions
** - unpaired Student's t, Mann-Whitney U and Pearson Chi-square tests
Ao - aorta, BMI - body mass index, dtE - E wave deceleration time, HRR 1 - heart rate recovery at 1st minute, IVRT - isovolumic relaxation time, IVS - interventricular septum, LA - left atrium, LATs - lateral mitral annular systolic velocity, LATe - lateral mitral annular early diastolic velocity, LATa - lateral mitral annular late diastolic velocity, LVEDD - left ventricular end-diastolic diameter, LVEF - left ventricular ejection fraction, LVESD - left ventricular end-systolic diameter, LVM - left ventricular mass, METs - metabolic equivalent unit, PW - posterior wall, RV - right ventricle, RVs - lateral tricuspid annular systolic velocity, RVe - lateral tricuspid annular early diastolic velocity, RVa - lateral tricuspid annular late diastolic velocity, SEPs - septal annular systolic velocity, SEPe - septal annular early diastolic velocity, SEPa - septal annular late diastolic velocity

are impaired in obesity (7). However, this study did not find a significant difference in the tricuspid annulus TDI peak systolic velocity between the obese and non-obese group. Willens et al. (6) also reported that the tricuspid annulus TDI peak systolic velocities in patients with BMI>35 kg/m² were similar to the controls. On the other hand, Wong et al. (9) demonstrated that increased BMI was associated with right ventricular dysfunction in the obese patients and this finding was independent from sleep apnea (9). Willens and coworkers (8) reported that the right ventricular dysfunction improves following weight loss.

Previous studies have also demonstrated an association between impaired HRR and right ventricular dysfunction in obesity. Weight loss is associated with improved right ventricular functions and post-exercise first minute HRR among these

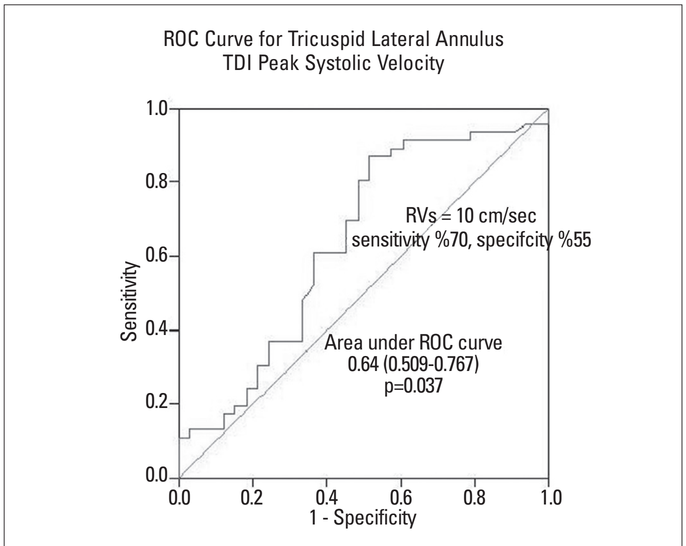

Figure 2. Diagnostic value of TDI peak systolic velocity in prediction of preserved heart rate recovery in obesity: ROC curve analysis
TDI – tissue Doppler imaging

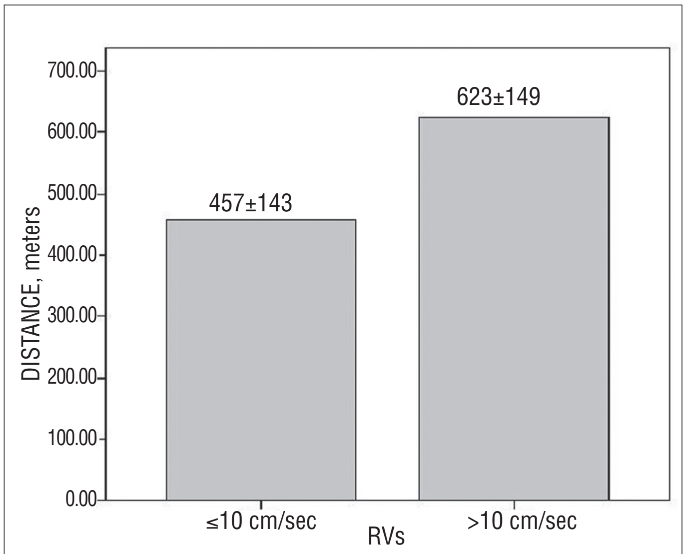

Figure 3. The exercise distance of the patients with and without right ventricular systolic dysfunction: RVs cut-off value - 10cm/sec
RVs – lateral tricuspid annular peak systolic velocity

patients (3, 8, 24). These studies revealed strong positive correlation between TDI derived echocardiographic parameters and HRR. In our study, there was no correlation between BMI and conventional echocardiographic parameters or HRR. However, the patients with impaired HRR and tricuspid annulus TDI peak systolic velocity <10 cm/sec had nonsignificant but larger BMI levels. More importantly, impaired HRR in obese patients predicted tricuspid annulus TDI peak systolic velocity <10 cm/sec. Obesity increases oxygen demand, causes insulin resistance and obstructive sleep apnea (34-37). All of these mechanisms may contribute to the right ventricular dysfunction. Obese patients with impaired HRR should be considered for echocardiographic evaluation to assess the right ventricular function.

Obese patients with impaired HRR were found to have reduced basal septum systolic velocities. This finding corroborates well with the literature and can be interpreted as the diagnostic utility of tissue Doppler in predicting the subclinical left ventricular systolic dysfunction (6). Although the previous studies revealed the presence of diastolic dysfunction in obesity, our patients with or without impaired HRR were similar in terms of left ventricular diastolic functions (4-6, 34, 38, 39).

Limitations of the study

Our study group was heterogeneous including relatively high number of female, diabetic, and hypertensive patients who were under medical treatment. Second, we did not exclude the patients with obstructive sleep apnea. However, both subgroups were similar in terms of BMI, HRR, and conventional echocardiographic parameters. Also, Wong et al. (9) demonstrated that subclinical right ventricular dysfunction in obesity is independent from obstructive sleep apnea, diabetes, and hypertension. This study builds on the reliability of our findings.

Conclusion

Post-exercise first minute impaired HRR is associated with right ventricular dysfunction in the obese population. Both HRR and right ventricular systolic functions closely correlate with exercise distance and METs. Obese patients with impaired HRR should be considered for echocardiographic evaluation in order to assess right ventricular systolic functions.

References

1. Noppa H, Bengtsson C, Wedel H, Wilhelmsen L. Obesity in relation to morbidity and mortality from cardiovascular disease. Am J Epidemiol 1980; 111: 682-92.
2. Kenchaiah S, Evans JC, Levy D, Wilson PW, Benjamin EJ, Larson MG, et al. Obesity and the risk of heart failure. N Engl J Med 2002; 347: 305-13.
3. Maniscalco M, Arciello A, Zedda A, Faraone S, Verde R, Giardiello C, et al. Right ventricular performance in severe obesity. Effect of weight loss. Eur J Clin Invest 2007; 37: 270-5.
4. Peterson LR, Waggoner AD, Schechtman KB, Meyer T, Gropler RJ, Barzilai B, et al. Alterations in left ventricular structure and function in young healthy obese women assessment by echocardiography and tissue doppler imaging. J Am Coll Cardiol 2004; 43: 1399-404.
5. Sharpe JA, Naylor LH, Jones TW, Davis EA, O'Driscoll G, Ramsay JM, et al. Impact of obesity on diastolic function in subjects < or = 16 years of age. Am J Cardiol 2006; 98: 691-3.
6. Willens HJ, Chakko SC, Lowery MH, Byers P, Labrador E, Gallagher A, et al. Tissue Doppler imaging of the right and left ventricle in severe obesity (body mass index >35 kg/m^2). Am J Cardiol 2004; 94: 1087-90.
7. Otto ME, Belohlavek M, Khandheria B, Gilman G, Svatikova A, Somers V. Comparison of right and left ventricular function in obese and nonobese men. Am J Cardiol 2004; 93: 1569-72.
8. Willens HJ, Chakko SC, Byers P, Chirinos JA, Labrador E, Castrillon JC, et al. Effects of weight loss after gastric bypass on right and left

ventricular function assessed by tissue Doppler imaging. Am J Cardiol 2005; 95: 1521-4.
9. Wong CY, O'Moore-Sullivan T, Leano R, Hukins C, Jenkins C, Marwick TH. Association of subclinical right ventricular dysfunction with obesity. J Am Coll Cardiol 2006; 47: 611-6.
10. Alam M, Wardell J, Andersson E, Samad BA, Nordlander R. Characteristics of mitral and tricuspid annular velocities determined by pulsed wave Doppler tissue imaging in healthy subjects. J Am Soc Echocardiogr 1999; 12: 618-28.
11. Park HS, Naik SD, Aronow WS, Visintainer PF, Das M, McClung JA, et al. Differences of lateral and septal mitral annulus velocity by tissue Doppler imaging in the evaluation of left ventricular diastolic function. Am J Cardiol 2006; 98: 970-2.
12. Kukulski T, Hubbert L, Arnold M, Wranne B, Hatle L, Sutherland GR. Normal regional right ventricular function and its change with age: a Doppler myocardial imaging study. J Am Soc Echocardiogr 2000; 13: 194-204.
13. Caso P, Galderisi M, Cicala S, Cioppa C, D'Andrea A, Lagioia G, et al. Association between myocardial right ventricular relaxation time and pulmonary arterial pressure in chronic obstructive lung disease: analysis by pulsed Doppler tissue imaging. J Am Soc Echocardiogr 2001; 14: 970-7.
14. Cole CR, Foody JM, Blackstone EH, Lauer MS. Heart rate recovery after submaximal exercise testing as a predictor of mortality in a cardiovascularly healthy cohort. Ann Intern Med 2000; 132: 552-5.
15. Nishime EO, Cole CR, Blackstone EH, Pashkow FJ, Lauer MS. Heart rate recovery and treadmill exercise score as predictors of mortality in patients referred for exercise ECG. JAMA 2000; 284: 1392-8.
16. Morshedi-Meibodi A, Larson MG, Levy D, O'Donnell CJ, Vasan RS. Heart rate recovery after treadmill exercise testing and risk of cardiovascular disease events (The Framingham Heart Study). Am J Cardiol 2002; 90: 848-52.
17. Mora S, Redberg RF, Cui Y, Whiteman MK, Flaws JA, Sharrett AR, et al. Ability of exercise testing to predict cardiovascular and all-cause death in asymptomatic women: a 20-year follow-up of the Lipid Research Clinics Prevalence Study. JAMA 2003; 290: 1600 -7.
18. Cole CR, Blackstone EH, Pashkow FJ, Snader CE, Lauer MS. Heart-rate recovery immediately after exercise as a predictor of mortality. N Engl J Med 1999; 341: 1351-7.
19. Lauer MS, Okin PM, Larson MG, Evans JC, Levy D. Impaired heart rate response to graded exercise. Prognostic implications of chronotropic incompetence in the Framingham Heart Study. Circulation 1996; 93: 1520-6.
20. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, et al. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol 1994; 24: 1529 - 35.
21. Arai Y, Saul JP, Albrecht P, Hartley LH, Lilly LS, Cohen RJ, et al. Modulation of cardiac autonomic activity during and immediately after exercise. Am J Physiol 1989; 256 (1 Pt 2): H132-41.
22. Savin WM, Davidson DM, Haskell WL. Autonomic contribution to heart rate recovery from exercise in humans. J Appl Physiol 1982; 53: 1572-5.
23. Deniz F, Katırcıbaşı MT, Pamukçu B, Binici S, Sanisoğlu SY. Association of metabolic syndrome with impaired heart rate recovery and low exercise capacity in young male adults. Clin Endocrinol (Oxf) 2007; 66: 218-23.
24. Brinkworth G, Noakes M, Buckley J, Clifton P. Weight loss improves heart rate recovery in overweight and obese men with features of the metabolic syndrome. Am Heart J 2006; 152: 693. e1-e6.
25. Gibbons RJ, Balady GJ, Beasley JW. ACC/AHA guidelines for exercise testing: a report of the American College of Cardiology/ American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). J Am Coll Cardiol 1997; 30: 260-311.
26. Watanabe J, Thamilarasan M, Blackstone E, Thomas J, Lauer MS. Heart Rate Recovery Immediately After Treadmill Exercise and Left Ventricular Systolic Dysfunction as Predictors of Mortality The Case of Stress Echocardiography. Circulation 2001; 104: 1911-6.
27. Schiller NB, Shah PM, Crawford M, DeMaria A, Devereux R, Feigenbaum H, et al. and the American Society of Echocardiography Committee on Standards, Subcommittee on Quantitation of Two-Dimensional Echocardiograms. Recommendations for quantitation of left ventricle by two-dimensional echocardiography. J Am Soc Echocardiogr 1989; 2: 358-67.
28. Devereux RB, Alonso DR, Lutas EM, Gottlieb GJ, Campo E, Sachs I, et al. Echocardiographic assessment of LV hypertrophy: comparison to necropsy findings. Am J Cardiol 1986; 57: 450-8.
29. Teichholz LE, Kreulen T, Herman MV, Gorlin R. Problems in echocardiographic volume determinations: echocardiographic-angiocardiographic correlations in the presence or absence of asynergy. Am J Cardiol 1976; 37: 7-11.
30. Quinones MA, Otto CM, Stoddard M, Waggoner AD, Zoghbi WA. Recommendations for quantification of Doppler echocardiography. A report from the Doppler quantification task force of the nomenclature and standards committee of the American Society of Echocardiography. J Am Soc Echocardiogr 2002; 15: 167-84.
31. Nagueh SF, Middleton KJ, Kopelen HA, Zoghbi WA, Quinones MA. Doppler tissue imaging: a noninvasive technique for evaluation of left ventricular relaxation and estimation of filling pressures. J Am Coll Cardiol 1997; 30: 1527-33.
32. Cheng YJ, Lauer MS, Earnest CP, Church TS, Kampert JB, Gibbons LW, et al. Heart rate recovery following maximal exercise testing as a predictor of cardiovascular disease and all-cause mortality in men with diabetes. Diabetes Care 2003; 26: 2052-7.
33. Lipinski MJ, Vetrovec GW, Froelicher VF. Importance of the first two minutes of heart rate recovery after exercise treadmill testing in predicting mortality and the presence of coronary artery disease in men. Am J Cardiol 2004; 93: 445-9.
34. Alpert MA. Obesity cardiomyopathy: pathophysiology and evolution of the clinical syndrome. Am J Med Sci 2001; 321: 225-36.
35. Peterson LR, Herrero P, Schechtman KB, Racette SB, Waggoner AD, Kisrieva-Ware Z, et al. Effect of obesity and insulin resistance on myocardial substrate metabolism and efficiency in young women. Circulation 2004; 109: 2191-6.
36. Hintz KK, Aberle NS, Ren J. Insulin resistance induces hyperleptinemia, cardiac contractile dysfunction but not cardiac leptin resistance in ventricular myocytes. Int J Obes Relat Metab Disord 2003; 27: 1196-203.
37. Guidry UC, Mendes LA, Evans JC, Levy D, O'Connor GT, Larson MG, et al. Echocardiographic features of the right heart in sleep-disordered breathing: the Framingham Heart Study. Am J Respir Crit Care Med 2001; 164: 933-8.
38. Tanalp AC, Bitigen A, Çevik C, Demir D, Özveren O, Tigen K, et al. The role of tissue Doppler study in the assessment of left ventricular dysfunction in obesity. Acta Cardiol 2008; 63: 541-6.
39. Bitigen A, Çevik C, Demir D, Tanalp AC, Dündar C, Tigen K, et al. The frequency of angiotensin-converting enzyme genotype and left ventricular functions in the obese population. Congest Heart Fail 2007; 13: 323-7.