Diastolic stress test echocardiography in patients with suspected heart failure with preserved ejection fraction: a pilot study

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Abstract

Aims The purpose of this pilot study was to assess the potential usefulness of diastolic stress test (DST) echocardiography in patients with suspected heart failure with preserved ejection fraction (HFP EF).

Methods and results Patients with suspected HFP EF (left ventricular ejection fraction ≥ 50%, exertional dyspnoea, septal E/e′ at rest 9–14, and N-terminal pro-B-type natriuretic peptide (NT-proBNP) at rest < 220 pg/mL; n = 13) and a control group constituted from asymptomatic patients with arterial hypertension (n = 19) and healthy subjects (n = 18) were included. All patients were analysed by two-dimensional and Doppler echocardiography at rest and during exercise (DST) and underwent cardiopulmonary exercise testing and NT-proBNP analysis during exercise. HFP EF during exercise was defined as exertional dyspnoea and peak VO₂ ≤ 20.0 mL/min/kg. In patients with suspected HFP EF at rest, 84.6% of these patients developed HFP EF during exercise, whereas in the group of asymptomatic patients with hypertension and healthy subjects, the rate of developed HFP EF during exercise was 0%. Regarding the diagnostic performance of DST to detect HFP EF during exercise, an E/e′ ratio > 15 during exercise was the most accurate parameter to detect HFP EF (accuracy 86%), albeit a low sensitivity (45.5%). Nonetheless, combining E/e′ with tricuspid regurgitation (TR) velocity > 2.8 m/s during exercise provided a significant increase in the sensitivity to detect patients with HFP EF during exercise (sensitivity 72.7%, specificity 79.5%, and accuracy 78%). Consistent with these findings, an increase of E/e′ was significantly linked to worse peak VO₂, and the combination of an increase of both E/e′ and TR velocity was associated with elevated NT-proBNP values during exercise.

Conclusions The findings of this pilot study suggest that DST using E/e′ ratio and TR velocity could be of potential usefulness to diagnose HFP EF during exercise in patients with suspected HFP EF at rest.

Keywords Diastolic stress test; Heart failure with preserved ejection fraction; Exercise echocardiography; Exertional dyspnoea

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Introduction

Diagnosis of heart failure (HF) with preserved ejection fraction (HFP EF) is still challenging and has been built on the basis of echocardiographic analyses at rest for many years.1,2 However, because many patients with HFP EF have symptoms such as dyspnea only during exercise and because non-invasive echocardiographic analyses at rest...
could be insufficiently sensitive to identify these patients,3–6 the potential usefulness of diastolic stress test (DST) echocardiography in this setting has been suggested.7–16 In line with this, several studies have shown that left ventricular (LV) diastolic alterations are more manifest during exercise than at rest in HFpEF.17,18 However, it remains uncertain why some patients with diastolic dysfunction remain asymptomatic during exercise and others not. In addition, many patients with signs and symptoms of HFpEF fall into the “grey zone” of key echocardiographic diagnostic parameters, such as E/e’ 8–15.2 Hence, a technique that may accurately categorize these borderline patients could be of great importance in clinical practice.19 In this respect, we hypothesized that DST could identify with adequate sensitivity and specificity patients with HFpEF who have inconclusive criteria at rest.

The purpose of this study was to assess the potential usefulness of DST in patients with suspected HFpEF by analysing patients with indeterminate criteria for HFpEF at rest and a control group constituted from asymptomatic patients with arterial hypertension (HT) and healthy subjects.

Methods

Study design

This study was a pilot single-centre study with the aim to assess the potential usefulness of DST in patients with suspected HFpEF. Pre-screening was obtained within the standard of care work-up in the Department of Cardiology at the Medical University of Graz. Eligible subjects meeting inclusion/exclusion criteria were considered for the study. Patients were recruited between 2012 and 2014 in the Department of Cardiology at the Medical University of Graz, Graz, Austria. During the screening visit, medical history of the patient as well as demographic data, physical examination to assess congestion and signs of HF, vital signs, New York Heart Association class evaluation, complete laboratory measurement [including N-terminal pro-B-type natriuretic peptide (NT-proBNP)], questionnaires, electrocardiogram, ambulatory blood pressure measurement, cardiopulmonary exercise testing, detailed rest echocardiography, and DST were performed.

Study patients

The study included 13 ambulatory patients with suspected HFpEF (left ventricular ejection fraction (LVEF) ≥ 50%, exertional dyspnoea, septal E/e’ at rest 9–14, and NT-proBNP at rest < 220 pg/mL) and a control group constituted from 19 asymptomatic patients with arterial HT and 18 healthy subjects. Asymptomatic patients with HT were determined by the presence or history of arterial HT (arterial blood pressure ≥ 140/90 mmHg) without any evidence of HF. Healthy subjects were defined as individuals with absence of any disease and cardiovascular risk factors such as obesity, diabetes, HT, and hypercholesterolaemia, with no medication and with normal findings in transthoracic echocardiography according to the diagnostic criteria of the European Association of Cardiovascular Imaging (EACVI).20 Exercise HFpEF was defined by dyspnoea during exercise and objective evidence of inadequate functional capacity (i.e. peak VO₂ < 20 mL/min/kg).21,22

Exclusion criteria

In order to avoid causes of LV myocardial dysfunction other than HFpEF, patients with coronary artery disease were excluded (namely, patients with unstable angina or non-ST-segment elevation myocardial infarction, patients with ST-segment elevation acute myocardial infarction, subjects with coronary artery bypass graft, subjects with chronic stable angina, and patients with evidence of myocardial ischaemia). Moreover, with the purpose of excluding other causes of dyspnoea other than HFpEF, patients with the following characteristics were excluded: (i) chronic obstructive pulmonary disease (presence of a post-bronchodilator first second of forced expiration to the full, forced vital capacity ratio < 0.7023 and concomitant signs and symptoms of chronic obstructive pulmonary disease disease reference values on spirometry), asthma, or severe pulmonary disease defined as pulmonary pathology with requirement of supplemental oxygen or need of treatment with corticoids; (ii) severe kidney disease defined as estimated glomerular filtration rate < 30 mL/min/1.73m² for at least 3 months, history of renal transplantation, or severe acute renal failure with dialysis requirement; (iii) severe chronic liver disease or history of liver transplantation; (iv) congenital heart disease; (v) pericardial disease characterized by moderate or severe pericardial effusion (echo-free space in end-diastole ≥5 mm) or constrictive pericarditis; (vi) cardiomyopathy; (vii) valvular heart disease defined as mild, moderate, or severe mitral or aortic stenosis; moderate or severe non-functional mitral or tricuspid regurgitation (TR); and moderate or severe aortic regurgitation (according to the diagnostic criteria of the guidelines for the management of patients with valvular heart disease of the EACVI). Furthermore, to avoid underestimations of myocardial and mitral annular measurements, patients with valvular heart surgery, mitral annular calcification (≥5 mm), cardiac pacing, and poor two-dimensional quality in ≥2 myocardial segments of the LV were also excluded. In addition, to avoid mistakes or large variations in the measurements of the LV due to variability of R-R interval, patients with atrial or ventricular arrhythmias were also excluded.
Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee (clinical research project number 24-318 ex 11/12). All subjects before involvement in the study provided written informed consent.

Conventional echocardiography at rest

Two-dimensional and Doppler echocardiography at rest were performed in accordance with EACVI recommendations. LV end-systolic and end-diastolic volume, LVEF, stroke volume, and cardiac output were measured by the modified Simpson’s method from the apical four-chamber view. LV filling pressures were calculated by the ratio of early mitral diastolic inflow velocity to early diastolic mitral septal annular velocity (E/e’) and indirectly by the maximal jet velocity of the TR, using the Bernoulli’s equation: $4 \times (TR \text{ velocity})^2 + \text{right atrial pressure for pulmonary artery systolic pressure}$ calculation.

Exercise echocardiography (diastolic stress test) protocol

Patients were analysed during bicycle supine exercise echocardiographic test. The images were obtained from the apical four-chamber view, and a multistage supine bicycle exercise test was performed. The exercise period began with the subject riding 60 r.p.m. at 25 W and increasing the workload at 25 W each 8 min. When the patient reached the 75 W, the workload was increased 25 W each 5 min. Heart rate, blood pressure (by sphygmomanometer), and echocardiographic parameters were measured at rest, during each stage of exercise, at peak exercise (symptom-limited), and in the recovery period. The following endpoint parameters were obtained and analysed during DST:

- septal E/e’,
- LVEF, stroke volume, and cardiac output (apical four-chamber view),
- maximal jet velocity of the TR, and
- NT-proBNP.

Cardiopulmonary exercise testing

Ventilatory exchange, oxygen uptake (peak VO₂), and other cardiopulmonary variables were acquired during the CPET by averaging breath-by-breath measurements over 10 s intervals. A standard 12 lead electrocardiogram was monitored continuously for heart rate, ST-segment changes, and arrhythmias. Blood pressure was recorded at rest and then every 2 min.

Blood sample measurements

An intravenous polyethylene cannula was inserted prior to resting echocardiography. After 10 min of supine rest, venous blood was collected in an edetic acid tube; a second sample was obtained within 1 min following the termination of exercise, while stress images were being acquired. Samples were centrifuged, frozen at the Biobank Graz, and analysed after recruitment of the last patient. Plasma NT-proBNP levels were measured on the Elecsys proBNP platform (Roche Diagnostics, Mannheim, Germany) with chemiluminescence technology. The detection limit of the NT-proBNP assay was 5 pg/mL. All other parameters were determined by routine laboratory procedures.

Statistical analysis

Continuous data were presented as mean ± standard deviation and dichotomous data in percentage. Differences in continuous variables between groups were analysed using Student’s t-test. Categorical variables were compared by χ² test and Fisher’s exact test as appropriate. Comparisons between three or more groups were analysed using a one-way analysis of variance. All statistical analyses were performed with Statview 5.0 (SAS Institute) and SPSS 22.0 (IBM). Differences were considered statistically significant when $P < 0.05$.

Results

Clinical and echocardiographic characteristics of the study population at rest

A total of 50 subjects were included in the study (13 with suspected HFpEF, 19 asymptomatic patients with HT, and 18 healthy subjects). Clinical characteristics of these subjects are shown in Table 1. There were no significant differences in conventional and haemodynamic parameters such as LVEF, TR velocity, left atrial volume index, heart rate between patients with suspected HFpEF, asymptomatic patients with HT, and healthy subjects at rest (see Table 1). Nonetheless, patients with suspected HFpEF were older and had a higher BMI, higher NT-proBNP levels, LV mass index, and septal E/e’ at rest.
Diastolic and haemodynamic changes during exercise in patients with suspected heart failure with preserved ejection fraction

Patients with suspected HFpEF had significantly lower values of septal e’, stroke volume, and cardiac output as well as higher values of septal E/e’, TR velocity, and NT-proBNP during exercise than asymptomatic patients with HT and healthy subjects (see Tables 2 and 3). Consistent with these findings, 84.6% of patients with suspected HFpEF developed HFpEF during exercise, whereas in the group of asymptomatic patients with HT and healthy subjects, the rate of HFpEF during exercise was 0%.

Haemodynamic and myocardial characteristics of patients with heart failure with preserved ejection fraction during exercise

Patients with HFpEF during exercise had principally significantly higher values of septal E/e’ and TR velocity than those without HFpEF (see Table 4). In line with these findings, patients with developed HFpEF during exercise had significantly lower functional exercise capacity (peak VO₂) and higher NT-proBNP values than those without HFpEF (see Table 4).

Diagnostic performance of diastolic stress test to determine heart failure with preserved ejection fraction during exercise

Regarding the diagnostic performance of DST to detect HFpEF during exercise, an E/e’ ratio > 15 during exercise was the most accurate parameter to detect HFpEF (accuracy 86%), albeit has a low sensitivity (45.5%) (see Table 5). Nonetheless, combining E/e’ with TR velocity during exercise provided a significant increase in the sensitivity to detect patients with HFpEF during exercise (sensitivity 72.7%, specificity 79.5%, and accuracy 78%) (see Table 5). Consistent with these findings, an increase in E/e’ was significantly linked to worse peak VO₂, and the combination of an increase of both E/e’ and TR velocity was associated with elevated NT-proBNP values during exercise (see Figures 1 and 2).

Discussion

In the present study, analysing patients with suspected HFpEF and a control group constituted from asymptomatic patients with HT and healthy subjects, we found that in patients with suspected HFpEF at rest, 86.4% of these patients developed HFpEF during exercise, whereas in the group of asymptomatic patients with HT and healthy subjects, the rate of HFpEF during exercise was 0%.

Table 1 Clinical and echocardiographic characteristics of the study population

| Clinical and echocardiographic characteristics | Healthy subjects (n = 18) | Asymptomatic HT (n = 19) | Suspected HFpEF (n = 13) | P-value |
|------------------------------------------------|--------------------------|--------------------------|--------------------------|---------|
| Clinical characteristics                       |                          |                          |                          |         |
| Age, years                                     | 53.3 ± 6.2               | 59.2 ± 7.4               | 67.0 ± 7.4               | <0.01   |
| Men                                            | 50.0%                    | 63.2%                    | 30.8%                    | 0.20    |
| Body mass index, kg/m²                         | 24.1 ± 2.6               | 27.9 ± 3.1               | 28.6 ± 4.1               | <0.01   |
| Systolic blood pressure, mmHg                  | 106 ± 10                 | 115 ± 12                 | 117 ± 15                 | 0.04    |
| Diastolic blood pressure, mmHg                 | 72 ± 9                   | 81 ± 9                   | 79 ± 9                   | 0.01    |
| Heart rate, per min                            | 61 ± 7                   | 62 ± 9                   | 67 ± 11                  | 0.23    |
| Peak VO₂, mL/min/kg                            | 27.0 ± 7.8               | 21.5 ± 4.9               | 15.9 ± 3.2               | <0.01   |
| NT-proBNP at rest, pg/mL                       | 66.2 ± 43.7              | 68.6 ± 45.7              | 105.7 ± 71               | 0.09    |
| Hypertension                                   | 0%                       | 100%                     | 100%                     | <0.01   |
| Diabetes                                       | 0%                       | 15.8%                    | 23.1%                    | 0.12    |
| Coronary artery disease                        | 0%                       | 0%                       | 0%                       | n/a     |
| Atrial fibrillation                            | 0%                       | 0%                       | 0%                       | n/a     |
| Echocardiographic measurements at rest         |                          |                          |                          |         |
| LV ejection fraction, %                        | 60.3 ± 3.6               | 61.3 ± 3.9               | 61.8 ± 6.7               | 0.68    |
| LV mass index, g/m²                            | 67.7 ± 31.4              | 93.0 ± 19.7              | 93.6 ± 19.5              | <0.01   |
| Septal e’ mitral annular velocity by TDI, cm/s | 10.7 ± 2.5               | 7.4 ± 1.0                | 6.8 ± 1.6                | <0.01   |
| Mitrual early diastolic inflow velocity (E), cm/s | 74.5 ± 12.7            | 70.2 ± 10.2              | 68.2 ± 12.9              | 0.31    |
| Mitrual E/e’ septal ratio                      | 7.5 ± 1.8                | 9.5 ± 1.6                | 10.3 ± 2.2               | <0.01   |
| Tricuspid regurgitation velocity, m/s          | 2.02 ± 0.3               | 1.97 ± 0.3               | 2.1 ± 0.2                | 0.30    |
| LAVI, mL/m²                                    | 27.0 ± 6.7               | 29.1 ± 12.6              | 31 ± 5.9                 | 0.50    |

* e’, early diastolic peak velocity by pulsed tissue Doppler imaging; HFpEF, heart failure with preserved ejection fraction; HT, hypertension; LAVI, left atrial volume index; LV, left ventricular; n/a, not applicable; NT-proBNP, N-terminal pro-B-type natriuretic peptide; TDI, pulsed tissue Doppler imaging.

Data are expressed as mean ± standard deviation or percentages.
### Table 2  Diastolic changes during exercise in the study population

|                      | Healthy subjects (n = 18) | Asymptomatic HT (n = 19) | Suspected HfPEF (n = 13) | P-ANOVA value |
|----------------------|---------------------------|--------------------------|--------------------------|---------------|
| **Mitral Septal E/e’** |                           |                          |                          |               |
| At rest              | 7.5 ± 1.8                 | 9.5 ± 1.6                | 10.3 ± 2.2               |               |
| During exercise      | 8.1 ± 1.5                 | 9.3 ± 1.7                | 14.1 ± 3.1               | <0.01         |
| P-value              | 0.16                      | 0.61                     | <0.01                    |               |
| **NT-proBNP, pg/mL** |                           |                          |                          |               |
| At rest              | 66.2 ± 43.7               | 68.6 ± 45.7              | 105.7 ± 71.0             |               |
| During exercise      | 74.6 ± 42.2               | 71.7 ± 49.3              | 125.7 ± 92.4             | 0.04          |
| P-value              | 0.27                      | <0.01                    | 0.02                     |               |
| **TR, m/s**          |                           |                          |                          |               |
| At rest              | 2.03 ± 0.2                | 1.97 ± 0.3               | 2.1 ± 0.2                |               |
| During exercise      | 2.00 ± 0.2                | 2.12 ± 0.6               | 2.52 ± 0.6               | 0.02          |
| P-value              | 0.92                      | 0.05                     | 0.01                     |               |
| **Mitral septal e’** |                           |                          |                          |               |
| At rest              | 10.7 ± 2.5                | 7.4 ± 1.0                | 6.8 ± 1.6                | <0.01         |
| During exercise      | 14.8 ± 2.6                | 11.3 ± 1.4               | 9.2 ± 1.7                | <0.01         |
| P-value              | <0.01                     | <0.01                    | <0.01                    |               |

HfPEF, heart failure with preserved ejection fraction; HT, hypertension; NT-proBNP, N-terminal pro-B-type natriuretic peptide; TR, tricuspid regurgitation.

### Table 3  Haemodynamic changes during exercise in the study population

|                      | Healthy subjects (n = 18) | Asymptomatic HT (n = 19) | Suspected HfPEF (n = 13) | P-ANOVA value |
|----------------------|---------------------------|--------------------------|--------------------------|---------------|
| **Stroke volume, mL**|                           |                          |                          |               |
| At rest              | 50.9 ± 12.8               | 52.8 ± 12.1              | 45.4 ± 11.3              |               |
| During exercise      | 70.0 ± 16.2               | 61.5 ± 13.2              | 52.4 ± 12.0              | 0.05          |
| P-value              | <0.01                     | <0.01                    | <0.01                    |               |
| **Cardiac output, L/min** |                           |                          |                          |               |
| At rest              | 3.1 ± 0.6                 | 3.2 ± 0.7                | 3.0 ± 0.6                |               |
| During exercise      | 7.8 ± 2.0                 | 6.6 ± 1.5                | 5.4 ± 0.9                | <0.01         |
| P-value              | <0.01                     | <0.01                    | <0.01                    |               |

HfPEF, heart failure with preserved ejection fraction; HT, hypertension.

### Table 4  Diastolic and haemodynamic differences in patients with developed HfPEF during exercise

|                                | Non-HF (n = 37) | HfPEF (n = 13) | P-value |
|--------------------------------|----------------|---------------|---------|
| E/e’ septal > 15 during exercise | 3.7%           | 45.5%         | <0.01   |
| TR > 2.8 m/s during exercise    | 20.5%          | 36.4%         | 0.28    |
| No increase of SV during exercise | 2.6%          | 9.1%          | 0.27    |
| No increase of CO during exercise | 0%             | 0%            | n/a     |
| NT-proBNP during exercise > 125 pg/mL | 10.3%      | 36.4%         | 0.03    |
| NT-proBNP during exercise > 220 pg/mL | 2.6%       | 18.2%         | 0.05    |
| Peak VO2, mL/min/kg             | 24.2 ± 6.9     | 15.0 ± 2.4    | <0.01   |

CO, cardiac output; HF, heart failure; HfPEF, heart failure with preserved ejection fraction; SV, stroke volume; TR, tricuspid regurgitation.

### Table 5  Diagnostic performance of diastolic stress test to detect HfPEF during exercise

| Variable                              | Sensitivity (%) | Specificity (%) | VPP (%) | VPN (%) | Accuracy (%) |
|---------------------------------------|-----------------|-----------------|---------|---------|--------------|
| E/e’ septal > 15 or TR > 2.8 m/s during exercise | 72.7            | 79.5            | 50      | 91.2    | 78           |
| E/e’ septal > 15 during exercise alone | 45.5            | 97.4            | 83.3    | 86.3    | 86           |
| TR > 2.8 m/s during exercise alone     | 36.4            | 79.5            | 33.3    | 81.6    | 70           |
| No increase of SV during exercise      | 9.1             | 97.4            | 50      | 79.1    | 78           |
| NT-proBNP during exercise > 125 pg/mL  | 36.4            | 89.7            | 50      | 83.3    | 78           |
| NT-proBNP during exercise > 220 pg/mL  | 18.2            | 97.4            | 66.7    | 80.8    | 80           |

HfPEF, heart failure with preserved ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; SV, stroke volume; TR, tricuspid regurgitation; VPN, negative predictive value; VPP, positive predictive value.
subjects, the rate of developed HFpEF during exercise was 0%. Moreover, DST had a diagnostic accuracy of 78% to detect HFpEF during exercise when elevations of either $E/e'$ or TR velocity were combined as rule-in parameters.

Rest echocardiography remains an important method to characterize the underlying functional and structural changes in HFpEF, and $E/e'$ ratio constitutes a key parameter in the evaluation of these patients. The $E/e'$ ratio $\geq 15$ if using $e'$ of septal site of the mitral annulus or $\geq 13$ if using average values of septal and lateral sites indicates accurately increased LV end-diastolic pressure, whereas an $E/e'$ value $< 8$ indicates normal filling pressures. Several studies have shown that $E/e'$ $> 15$ may be able to provide stand-alone evidence of diastolic LV dysfunction without further need of serial non-invasive tests in HFpEF patients. However, many patients with signs and symptoms of HFpEF fall into the “grey zone” of key echocardiographic diagnostic parameters, such as $E/e'$ $8–15$, and thus, other echocardiographic indices should be used. Hence, a technique that may accurately categorize these borderline patients with $E/e'$ $8–15$ as truth HFpEF could be of great importance in the clinical practice.

Several studies have shown that LV diastolic alterations are more manifest during exercise than at rest in HFpEF. Nonetheless, in patients with suspected HFpEF (i.e. exertional dyspnoea and borderline values of $E/e'$ and NT-proBNP), an optimal diagnostic approach to diagnose HFpEF remains uncertain. In the present study an $E/e'$ ratio $> 15$ during

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**Figure 1** Association of an increase of $E/e'$ septal with worse functional capacity (peak VO$_2$).

![Graph showing association of increased E/e' septal with VO2](image1)

**Figure 2** Association of an increase of $E/e'$ septal and tricuspid regurgitation (TR) velocity with an increase of N-terminal pro-B-type natriuretic peptide (NT-proBNP) values during exercise. TR and NT-proBNP values were not available in five patients during exercise.

![Graph showing association of increased E/e' septal and TR velocity with NT-proBNP](image2)

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exercise was the most accurate parameter to detect HFpEF during exercise (accuracy 86%) in patients with suspected HFpEF in the “grey zone,” albeit has a low sensitivity (45.5%). Nonetheless, combining E/e’ with TR velocity provided a significant increase in the sensitivity to detect patients with HFpEF during exercise (sensitivity 72.7%, specificity 79.5%, and accuracy 78%). In addition, both an increase of E/e’ and TR velocity during exercise were significantly linked to worse peak VO₂ and elevated NT-proBNP values during exercise. These findings are in agreement with recent studies.³⁰ In this regard, Obokata et al.¹ using invasive LV filling pressure measurements found that the combination of E/e’ and TR velocity during exercise had an adequate sensitivity and specificity to diagnose HFpEF. In addition, Donal et al.³¹ showed that both E/e’ and TR velocity during exercise were the main echocardiographic parameters linked to worse cardiovascular prognosis in patients with HFpEF. Furthermore, Kosmala et al.³² demonstrated that E/e’ during exercise was significantly linked to cardiovascular outcomes in patients with suspected HFpEF. Therefore, we consider that the combination of E/e’ and TR velocity during exercise could be of clinical usefulness in patients in the “grey zone” with suspected HFpEF.

Limitations

Some considerations should be taken into account on this study. One main limitation is the low sample size of this pilot study. Hence, the findings of this study regarding the potential usefulness of DST in the setting of patients with suspected HFpEF should be validated in further studies with larger sample size. In addition, it is important to note that the diagnosis of HFpEF during exercise was not validated by using invasive gold standard measurements such as LV filling pressures or pulmonary capillary wedge pressure. Therefore, the results of this study regarding the diagnostic performance of DST in the setting of patients with suspected HFpEF should be confirmed in further studies with invasive measurements. In addition, it is worth highlighting that the findings of this study are lacking prognostic significance because in this study, no outcomes analyses were performed. However, recent studies have suggested that an elevated E/e’ and TR during exercise in patients with HFpEF are markers of poor cardiovascular outcomes in these patients.³⁰,³²

Conclusions

The findings of this pilot study suggest that DST using E/e’ ratio and TR velocity could be of potential usefulness to diagnose HFpEF during exercise in patients with suspected HFpEF at rest. Further larger studies analysing the diagnostic performance of DST in patients with suspected HFpEF are warranted, because the findings of this pilot suggest a clinical usefulness of DST in this setting.

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Conflict of interest

None declared.

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