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ΔΙΟΡΓΑΝΩΣΗ: ΚΑΡΔΙΟΛΟΓΙΚΗ ΕΤΑΙΡΕΙΑ ΒΟΡΕΙΟΥ ΕΛΛΑΔΟΣ



ΣΤΡΟΓΓΥΛΟ ΤΡΑΠΕΖΙ

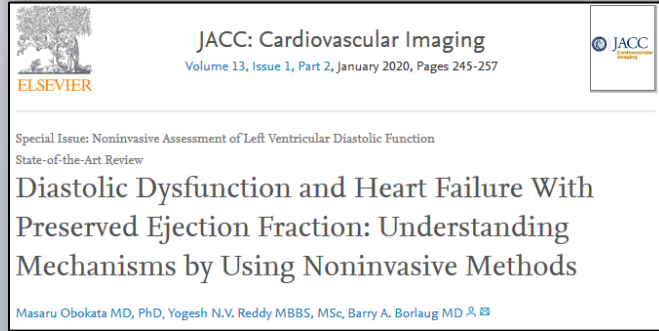
Δυναμική Ηχωκαρδιογραφία

***Stress echo για διαστολική δυσλειτουργία:
Πότε και σε ποιους ασθενείς;***

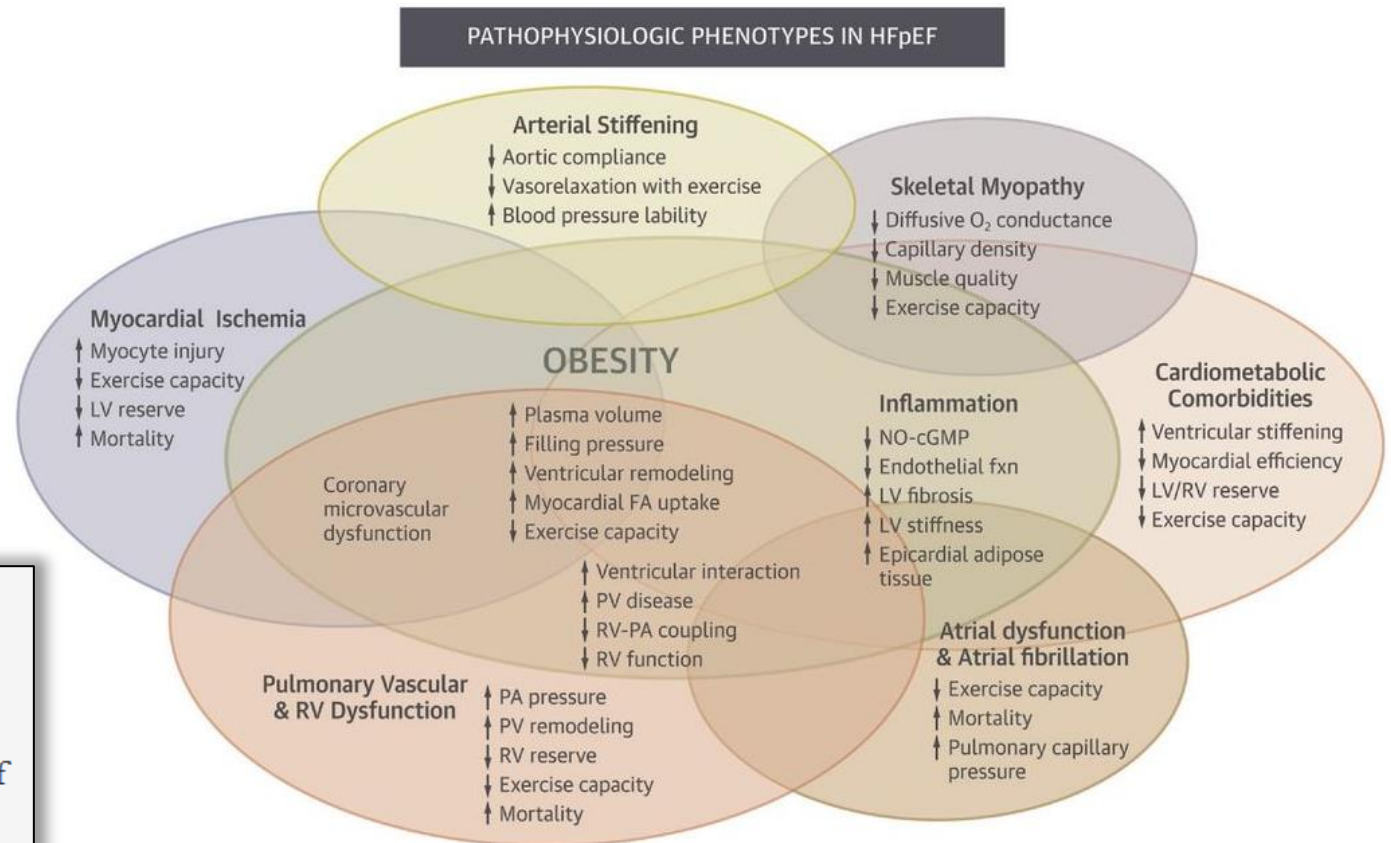
ΚΑΣΜΕΡΙΔΗΣ ΧΑΡΑΛΑΜΠΟΣ

ΚΑΡΔΙΟΛΟΓΟΣ, ΕΠΙΜΕΛΗΤΗΣ Β' Γ.Ν.ΒΕΡΟΙΑΣ





CENTRAL ILLUSTRATION: Phenotypes of HFpEF



HFpEF is a heterogeneous syndrome, and categorizing patients based upon pathophysiology may provide phenotype-specific therapies.

Echocardiography provides valuable information for assessing pathophysiological mechanisms, phenotyping, and diagnosis in cases of HFpEF.

JACC: CARDIOVASCULAR IMAGING
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VOL. 13, NO. 1, 2020

STATE-OF-THE-ART REVIEW

Diastolic Stress Test Invasive and Noninvasive Testing

Jong-Won Ha, MD, PhD,^a Oyvind S. Andersen, MD,^b Otto A. Smiseth, MD, PhD^b

ABSTRACT

Diastolic dysfunction is a key factor in the pathogenesis of heart failure. Around 50% of cases of heart failure, the hemodynamic correlate of which is increased left ventricular filling pressure, are caused by diastolic dysfunction in the setting of apparently normal systolic function. Due to its high prevalence, diastolic dysfunction is often recognized as an incidental finding. Many patients have Doppler echocardiographic evidence of impaired diastolic function but do not have any symptoms of heart failure at rest. In many of these patients, symptoms of diastolic dysfunction occur only during exercise, as left ventricular filling pressure is normal at rest, but increases with exercise. This implies that filling pressures should also be measured during exercise. The diastolic stress test refers to the evaluation of diastolic function, either invasively or noninvasively, during exercise. This review focuses on the clinical need for diastolic stress testing, both invasively and noninvasively.

(J Am Coll Cardiol Img 2020;13:272-82) © 2020 by the American College of Cardiology Foundation.

HIGHLIGHTS

- Diastolic dysfunction is a key factor in the pathogenesis of heart failure.
- Frequently, symptoms of diastolic dysfunction occur only during exercise, as LV filling pressure is normal at rest, but increases with exercise.
- This implies that LV filling pressures should also be measured not only at rest but also during exercise.
- The diastolic stress test refers to the evaluation of diastolic function, either invasively or noninvasively, during exercise, and it will provide insights into cardiovascular hemodynamics.
- More work is needed to refine and standardize the methodology but the integration of diastolic stress testing into clinical practice will certainly enhance our understanding and better management of patients with diastolic dysfunction and exertional dyspnea.

ΠΟΙΟΣ Ο ΛΟΓΟΣ ΔΙΕΝΕΡΓΕΙΑΣ ΔΙΑΣΤΟΛΙΚΟΥ STRESS ECHO ;

**ΔΙΑΓΝΩΣΤΙΚΟΣ
ΛΟΓΟΣ**

**ΕΚΤΙΜΗΣΗ ΤΗΣ
ΣΟΒΑΡΟΤΗΤΑΣ
ΤΗΣ ΝΟΣΟΥ**

**ΠΡΟΓΝΩΣΤΙΚΟΣ
ΛΟΓΟΣ**

**ΕΥΡΕΣΗ ΑΣΘΕΝΩΝ
ΜΕ ΠΙΘΑΝΟ
ΟΦΕΛΟΣ ΑΠΟ
ΘΕΡΑΠΕΙΑ**

“ to assess exertional breathlessness, you must exert the breathless!”

ASE/EACVI GUIDELINES AND STANDARDS

(J Am Soc Echocardiogr 2016;29:277-314.)


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

Sherif F. Naguch, Chair, MD, FASE,¹ Otto A. Smiseth, Co-Chair, MD, PhD,² Christopher P. Appleton, MD,¹

Diastolic stress test should be performed in patients with first-degree diastolic dysfunction, without elevated left ventricular filling pressures at rest, if there are symptoms suggestive of heart failure, in particular exercise dyspnea, to answer the question whether the symptoms experienced by the patient result from diastolic reserve impairment

Hellenic Journal of Cardiology 64 (2022) 30–57


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journal homepage: <http://www.journals.elsevier.com/hellenic-journal-of-cardiology/>

Review Article

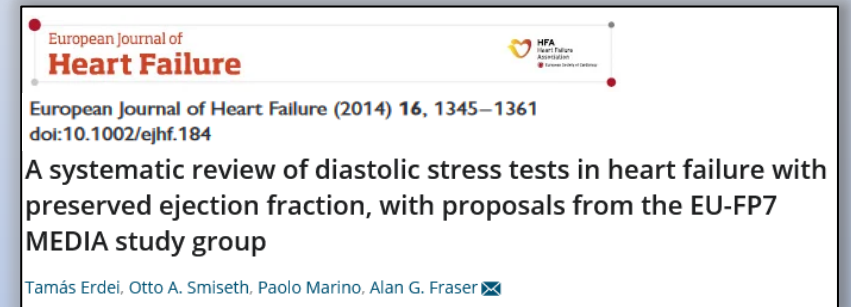
Updated knowledge and practical implementations of stress echocardiography in ischemic and non-ischemic cardiac diseases: An expert consensus of the Working Group of Echocardiography of the Hellenic Society of Cardiology



Nikolaos P.E. Kadoglou ^{1,2,**,†}, Constantinos H. Papadopoulos ^{3,*,†},
Konstantinos G. Papadopoulos ^{4,†}, Stefanos Karagiannis ^{5,†}, Ilias Karabinos ⁶,

Keypoints:	Evidence/Studies	Consensus status
<p><u>DSTE</u> may be indicated in patients with unexplained resting breathlessness, or exertional dyspnea and/or poor exercise capacity with <u>indeterminate diastolic function.</u></p>	<p>Expert opinion E</p>	<p>Consensus</p>
	<p><i>concomitant risk factors for diastolic dysfunction (older age, hypertension, obesity, diabetes, sedentary lifestyle)</i></p>	

Diagnostic guidelines for heart failure suggest wider indications for diastolic stress echocardiography. In this document, experts suggest a diastolic stress test in all suspected heart failure patients with preserved left ventricular ejection fraction, in whom other examinations, such as resting echocardiographic examination or measurement of natriuretic peptides, did not allow such a diagnosis to be confirmed, and the patients feel dyspnea, especially exertional dyspnea. The risk factors of developing heart failure with preserved ejection fraction of the left ventricle, such as age, hypertension, diabetes mellitus, sedentary lifestyle, overweight and obesity, should be borne in mind



**ΦΑΙΝΟΤΥΠΙΚΗ
ΕΤΕΡΟΓΕΝΕΙΑ ΤΟΥ
ΣΥΝΔΡΟΜΟΥ**


HFpEF scores (H_2 FPEF score)

JACC: Cardiovascular Imaging
Volume 13, Issue 1, Part 2, January 2020, Pages 245-257

ELSEVIER

Special Issue: Noninvasive Assessment of Left Ventricular Diastolic Function
State-of-the-Art Review

Diastolic Dysfunction and Heart Failure With Preserved Ejection Fraction: Understanding Mechanisms by Using Noninvasive Methods

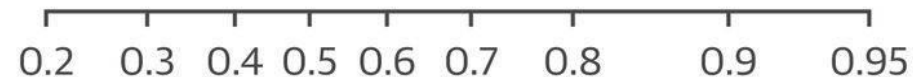
Masaru Obokata MD, PhD, Yogesh N.V. Reddy MBBS, MSc, Barry A. Borlaug MD 

	Clinical Variable	Values	Points
H_2	Heavy	Body mass index > 30 kg/m ²	2
	Hypertensive	2 or more antihypertensive medicines	1
F	Atrial Fibrillation	Paroxysmal or persistent	3
P	Pulmonary Hypertension	Doppler echocardiographic estimated right ventricular systolic pressure > 35 mmHg	1
E	Elder	Age > 60 years	1
F	Filling Pressure	Doppler echocardiographic E/e' > 9	1
H_2 FPEF score			Sum (0-9)

Total Points



Probability of HFpEF

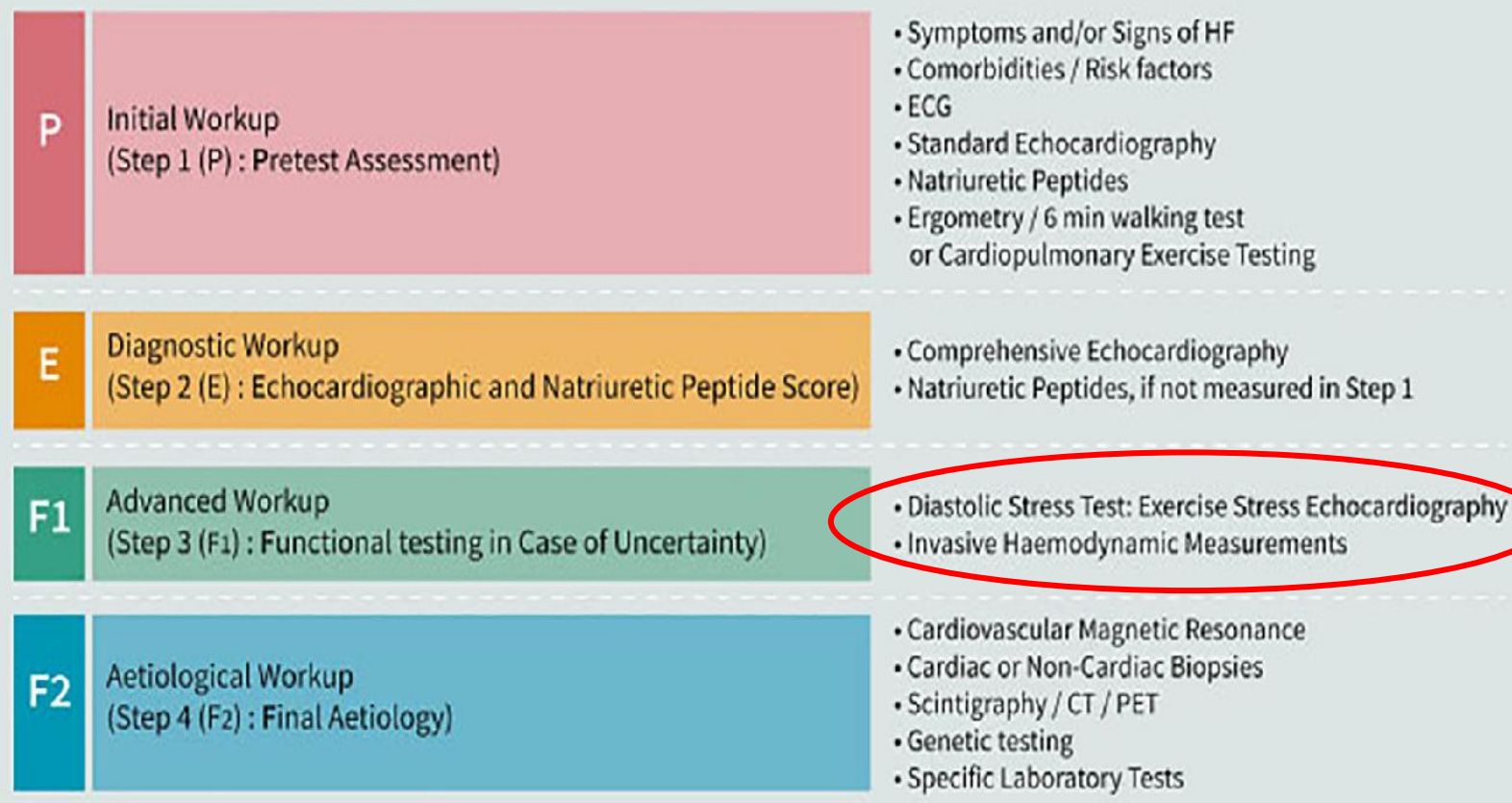


How to diagnose heart failure with preserved ejection fraction: the HFA-PEFF diagnostic algorithm: a consensus recommendation from the Heart Failure Association (HFA) of the European Society of Cardiology (ESC)

Bürkert Pieske^{1,2,3,4*}, Carsten Tschöpe^{1,2,5}, Rudolf A. de Boer⁶, Alan G. Fraser⁷, Stefan D. Anker^{1,2,5,8}, Erwan Donal⁹, Frank Edelmann^{1,2}, Michael Fu¹⁰, Marco Guazzi^{11,12}, Carolyn S.P. Lam^{13,14}, Patrizio Lancellotti¹⁵, Vojtech Melenovsky¹⁶, Daniel A. Morris¹, Eike Nagel^{17,18}, Elisabeth Pieske-Kraigher¹, Piotr Ponikowski¹⁹, Scott D. Solomon²⁰, Ramachandran S. Vasan²¹, Frans H. Rutten²², Adriaan A. Voors⁶, Frank Ruschitzka²³, Walter J. Paulus²⁴, Petar Seferovic²⁵, and Gerasimos Filippatos^{26,27}

Step 1 (P=Pre-test assessment) is typically performed in the ambulatory setting and includes assessment for heart failure symptoms and signs, typical clinical demographics (obesity, hypertension, diabetes mellitus, elderly, atrial fibrillation), and diagnostic laboratory tests, electrocardiogram, and echocardiography. In breathlessness, HFpEF can be suspected if there is a normal left ventricular (LV) ejection fraction, no significant heart valve disease or cardiac ischaemia, and at least one typical risk factor. Elevated natriuretic peptides support, but normal levels do not exclude a diagnosis of HFpEF. The second step (E: Echocardiography and Natriuretic Peptide Score) requires comprehensive echocardiography and is typically performed by a cardiologist. Measures include mitral annular early diastolic velocity (e'), LV filling pressure estimated using E/e' , left atrial volume index, LV mass index, LV relative wall thickness, tricuspid regurgitation velocity, LV global longitudinal systolic strain, and serum natriuretic peptide levels. Major (2 points) and Minor (1 point) criteria were defined from these measures. A score ≥ 5 points implies definite HFpEF; ≤ 1 point makes HFpEF unlikely. An intermediate score (2–4 points) implies diagnostic uncertainty, in which case Step 3 (F₁: Functional testing) is recommended with echocardiographic or invasive haemodynamic exercise stress tests. Step 4 (F₂: Final aetiology) is recommended to establish a possible specific cause of HFpEF or alternative explanations. Further research is needed for a better classification of HFpEF.

The HFA-PEFF Algorithm for the Diagnosis of HFpEF



Major (2 points) and Minor (1point) criteria were defined from STEP 2.

- A score ≥ 5 points implies definite HFpEF .
- ≤ 1 point makes HFpEF unlikely.
- An intermediate score (2–4 points) implies diagnostic uncertainty → STEP 3 & STEP 4.

HFpEF scores (HFA-PEFF score)



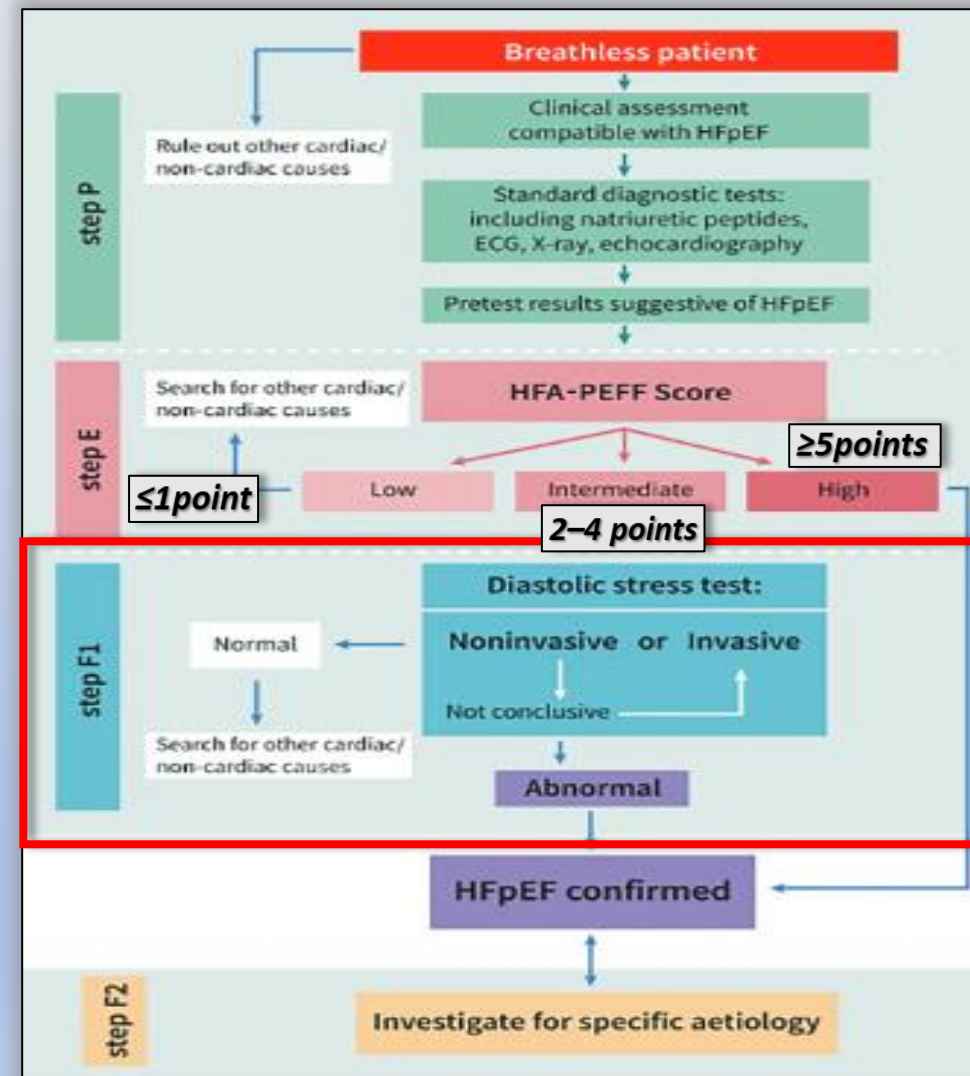
European Journal of Heart Failure (2020) 22, 391–412
doi:10.1002/ehf.1741

HFA CONSENSUS RECOMMENDATION

How to diagnose heart failure with preserved ejection fraction: the HFA-PEFF diagnostic algorithm: a consensus recommendation from the Heart Failure Association (HFA) of the European Society of Cardiology (ESC)

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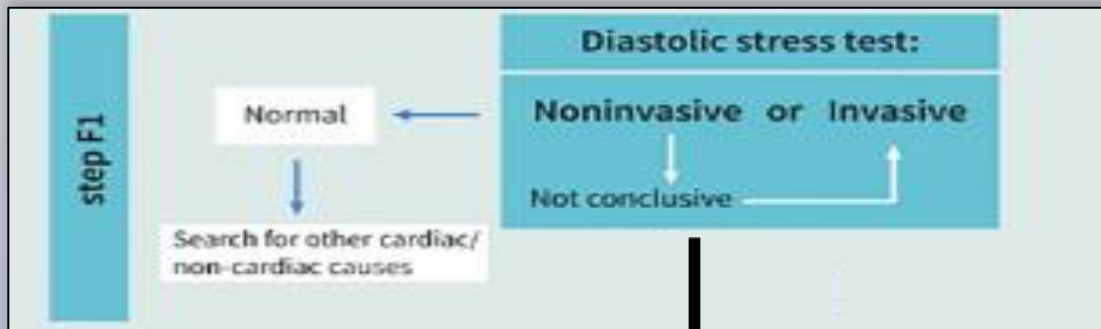
	Functional	Morphological	Biomarker (SR)	Biomarker (AF)
Major	septal e' < 7 cm/s or lateral e' < 10 cm/s or Average E/e' ≥ 15 or TR velocity > 2.8 m/s (PASP > 35 mmHg)	LAVI > 34 ml/m ² or LVMI ≥ 149/122 g/m ² (m/w) and RWT > 0,42 #	NT-proBNP > 220 pg/ml or BNP > 80 pg/ml	NT-proBNP > 660 pg/ml or BNP > 240 pg/ml
Minor	Average E/e' 9 -14 or GLS < 16 %	LAVI 29-34 ml/m ² or LVMI > 115/95 g/m ² (m/w) or RWT > 0,42 or LV wall thickness ≥ 12 mm	NT-proBNP 125-220 pg/ml or BNP 35-80 pg/ml	NT-proBNP 365-660 pg/ml or BNP 105-240 pg/ml
Major Criteria: 2 points		≥ 5 points: HFpEF		
Minor Criteria: 1 point		2-4 points: Diastolic Stress Test or Invasive Haemodynamic Measurements		



Flowchart of the HFA-PEFF diagnostic algorithm.

HFpEF scores (HFA-PEFF score)

2-4 points

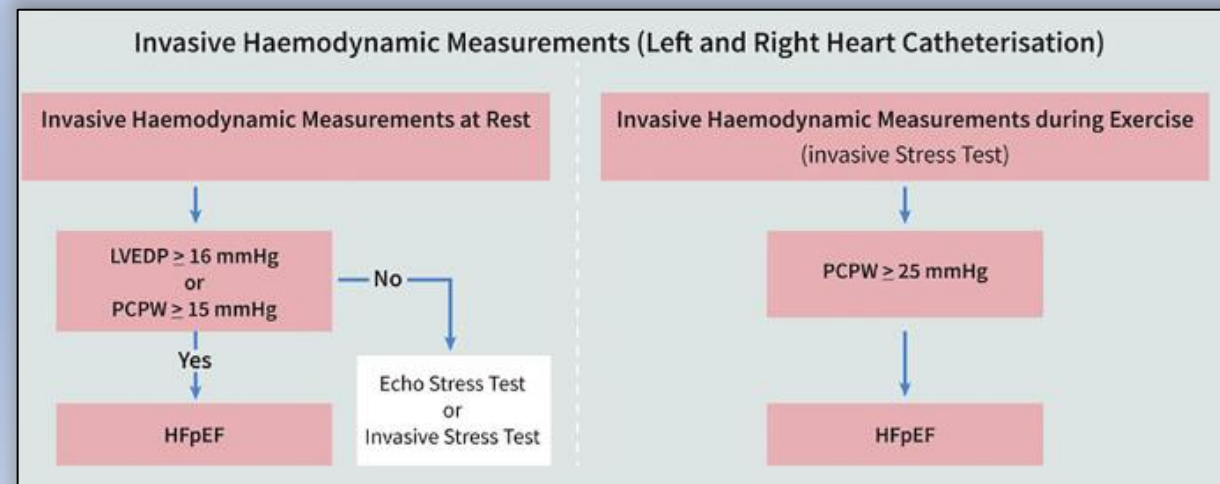
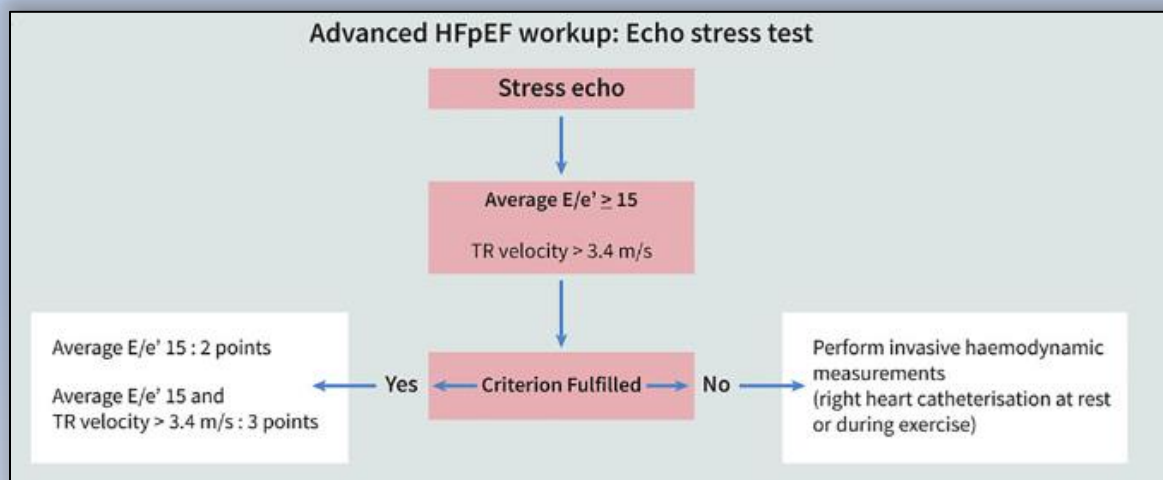


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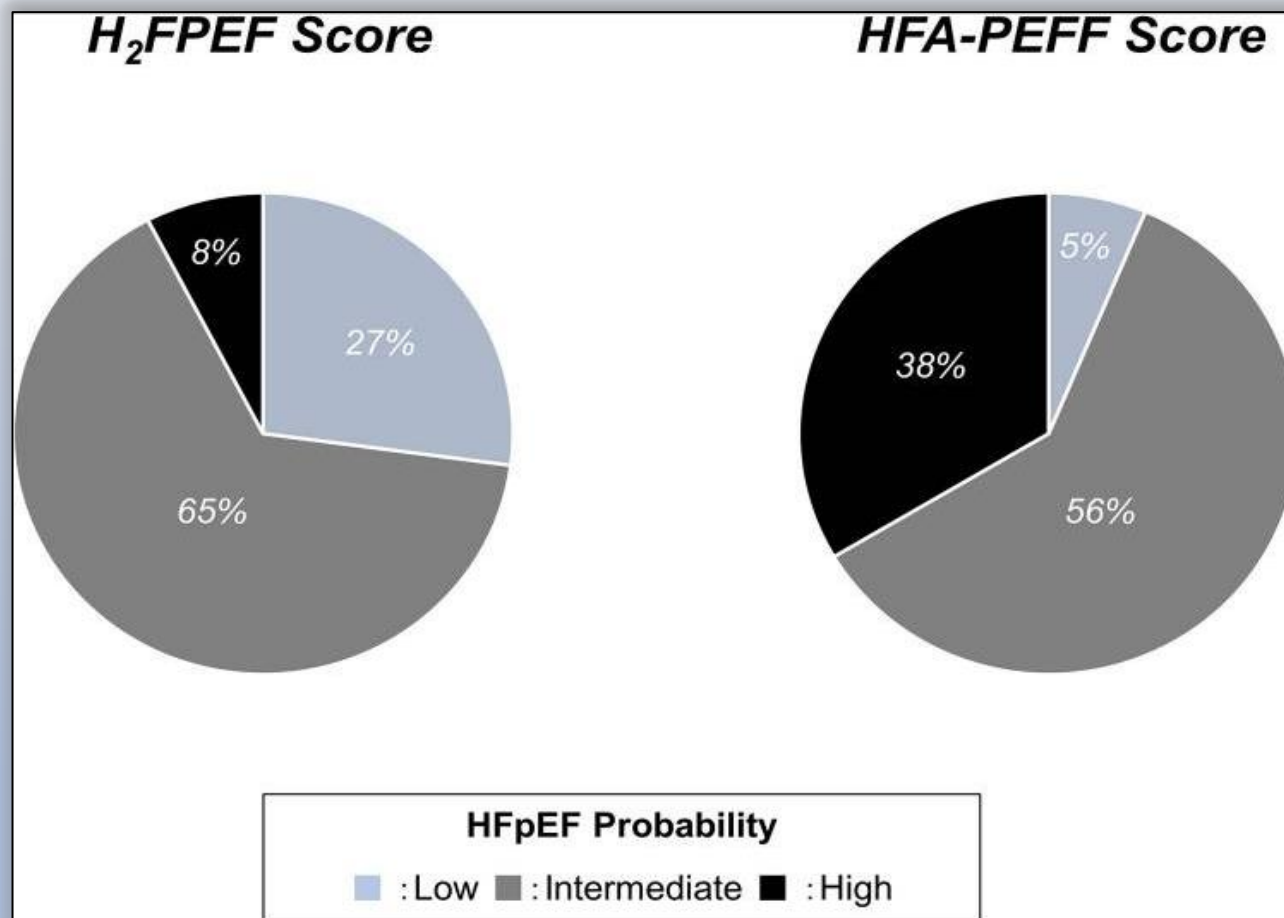
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HFpEF scores – H₂FPEF vs HFA-PEFF



SCIENTIFIC REPORTS
nature research

Sci Rep. 2022; 12: 13. PMID: PMC8742061
 Published online 2022 Jan 7. doi: [10.1038/s41598-021-03974-6](https://doi.org/10.1038/s41598-021-03974-6) PMID: [34996984](https://pubmed.ncbi.nlm.nih.gov/34996984/)

The H₂FPEF and HFA-PEFF algorithms for predicting exercise intolerance and abnormal hemodynamics in heart failure with preserved ejection fraction

Shiro Amanai,^{#1} Tomonari Harada,^{#1} Kazuki Kagami,^{1,2} Kuniko Yoshida,¹ Toshimitsu Kato,¹ Naoki Wada,³ and Masaru Obokata^{#1}

Distribution of H₂FPEF and HFA-PEFF scores among all participants. The H₂FPEF score was more likely to classify subjects into a low or intermediate probability while the HFA-PEFF score categorized them as a high probability.



1) Exercise using a supine bicycle is the recommended modality for diastolic SE as it allows the acquisition of Doppler recordings throughout the test and the non-invasive assessment of exercise diastolic function reserve.

2) Treadmill exercise SE is an alternative as diastolic abnormalities may persist after exercise.

We acquire echocardiographic images before and after the exercise, during the rest period, after appropriate decrease pulse when the measurement of E wave becomes possible.



European Heart Journal – Cardiovascular Imaging (2016) 17, 1191–1229
doi:10.1093/ehjci/jew190

**EACVI/ASE
RECOMMENDATION**

The clinical use of stress echocardiography in non-ischaemic heart disease: recommendations from the European Association of Cardiovascular Imaging and the American Society of Echocardiography

Patrizio Lancellotti^{1,2*}, Patricia A. Pellikka³, Werner Budts⁴, Farooq A. Chaudhry⁵, Erwan Donal⁶, Raluca Dulgheru¹, Thor Edvardsen⁷, Madalina Garbi⁸, Jong-Won Ha⁹, Garvan C. Kane³, Joe Kreeger¹⁰, Luc Mertens¹¹, Philippe Pibarot¹², Eugenio Picano¹³, Thomas Ryan¹⁴, Jeane M. Tsutsui¹⁵, and Albert Varga¹⁶

Review > [Hellenic J Cardiol. 2022 Mar-Apr;64:30-57. doi: 10.1016/j.hjc.2021.07.006.](#)

Epub 2021 Jul 28.

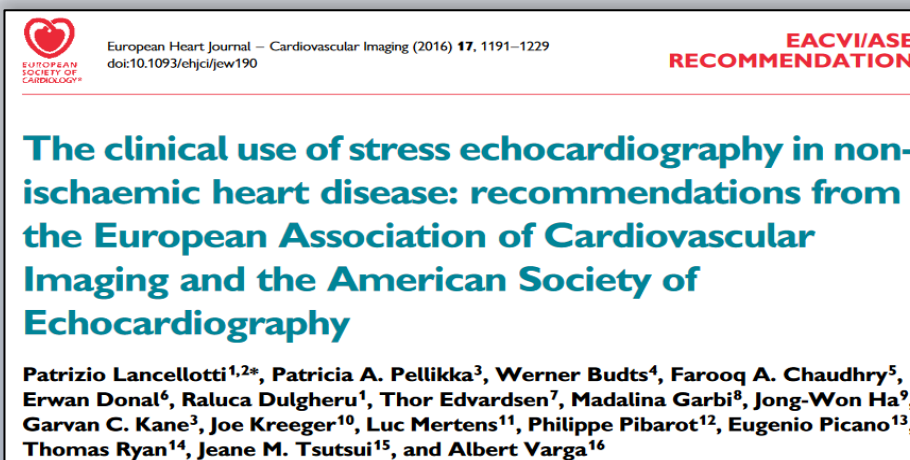
Updated knowledge and practical implementations of stress echocardiography in ischemic and non-ischemic cardiac diseases: An expert consensus of the Working Group of Echocardiography of the Hellenic Society of Cardiology

Nikolaos P E Kadoglou ¹, Constantinos H Papadopoulos ², Konstantinos G Papadopoulos ³,

Protocol of diastolic stress echocardiography.

Stage	Supine bicycle				Treadmill			
	MV inflow velocities (E and A waves)	Mitral annulus TDI (e' septal & lateral)	TR Vmax	LV views (4-, 2- and 3-CH view)	MV inflow Velocities (E and A waves)	Mitral annulus TDI (e' septal & lateral)	TR Vmax	LV views (4-, 2- and 3-CH view)
Rest	✓	✓	✓	✓	✓	✓	✓	✓
Each stage	✓	✓	✓	✓	✓	✓	✓	✓
Peak	✓	✓	✓	✓	✓	✓	✓	✓
Early recovery (1-2 min)	✓	✓		✓	✓	✓		✓

TDI, tissue doppler imaging; CH, chamber; TR Vmax, tricuspid regurgitation maximum velocity.



3) Preload augmentation by passive leg raise might also represent a non-exercise alternative since it provides additional information identifying patients with exercise-induced LV filling pressure elevation and lower exercise capacity.

Patients with relaxation abnormality and $E/e' < 15$ at rest but increased $E/e' > 15$ during leg raise, defined as 'unstable' relaxation abnormality, were older, more often female, and had lower diastolic reserve and exercise capacity when compared with patients with persistent $E/e' < 15$. In addition, e' response to passive leg raise was significantly correlated with diastolic reserve indexes during exercise.

Exercise

- ↑SV and ↑afterload
- ↑preload
- Functional status
- Very safe


- Respiratory/ other movement
- Often in early recovery

We cannot replace physical exercise with other stress methods such as dobutamine or quick heart stimulation, because the use of these methods in itself affects the diastolic function.



ΕΡΓΟΜΕΤΡΟ - Πρωτόκολλα



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doi:10.1093/ehjci/jew190

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 European Journal of
Heart Failure

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European Society of Cardiology

Original Article | [Free Access](#)

A systematic review of diastolic stress tests in heart failure with preserved ejection fraction, with proposals from the EU-FP7 MEDIA study group

Tamás Erdei, Otto A. Smiseth, Paolo Marino, Alan G. Fraser ✉

1) The European Association of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE) recommend a stepped protocol, starting at 25 Watt at 60 r.p.m. with the load increasing by 25 Watt every 3 min until the patient has reached his maximal predicted workload and/or maximal predicted heart rate (220 - age in years) and/or developed limiting symptoms.

2) Some patients cannot perform that protocol, and a ramped exercise test on a semi-supine bicycle at 60 r.p.m. starting at 15 Watt and with increments of 5 Watt every minute has also been proposed, to a submaximal target heart rate of 100–110/min or until the patient develops limiting symptoms (EU-FP7 MEDIA study group - Cardiff-MEDIA protocol).

None of these protocols have been shown to be superior to others.

European Journal of
Heart Failure



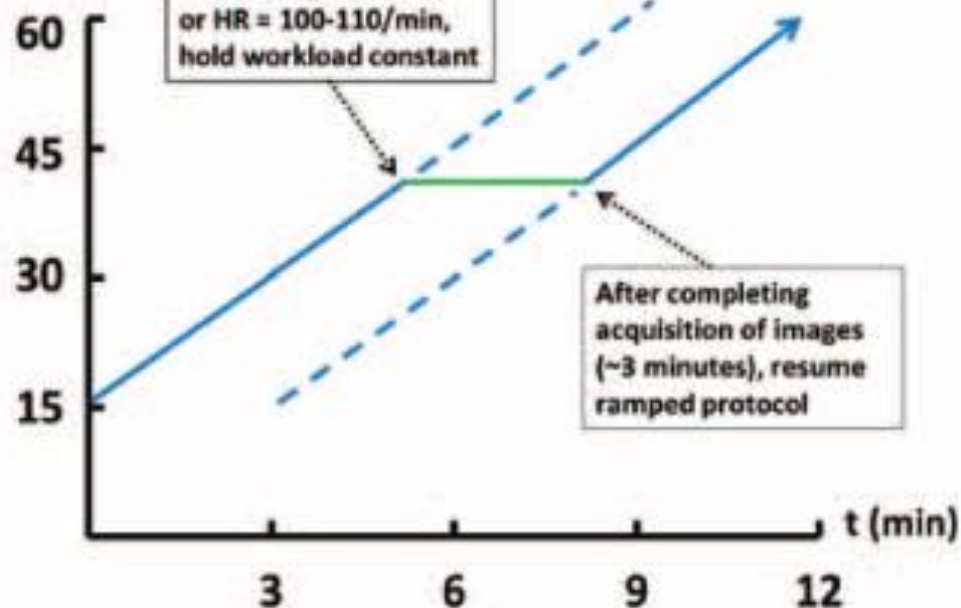
European Journal of Heart Failure (2014) 16, 1345–1361
doi:10.1002/ejhf.184

A systematic review of diastolic stress tests in heart failure with preserved ejection fraction, with proposals from the EU-FP7 MEDIA study group

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protocol on a semi-supine bicycle, starting at 15 W, with increments of 5 W/min to a submaximal target (heart rate 100–110 b.p.m., or symptoms). Measurements during submaximal and recovery stages should include changes from baseline in LV long-axis function and indirect echocardiographic indices of LV diastolic pressure.

Workload (w)



Acquisition of echocardiography images

At rest

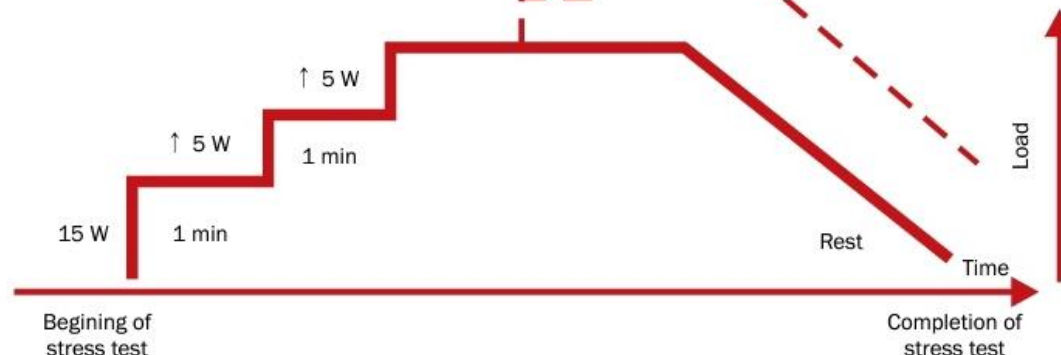
Acquisition of echocardiography images

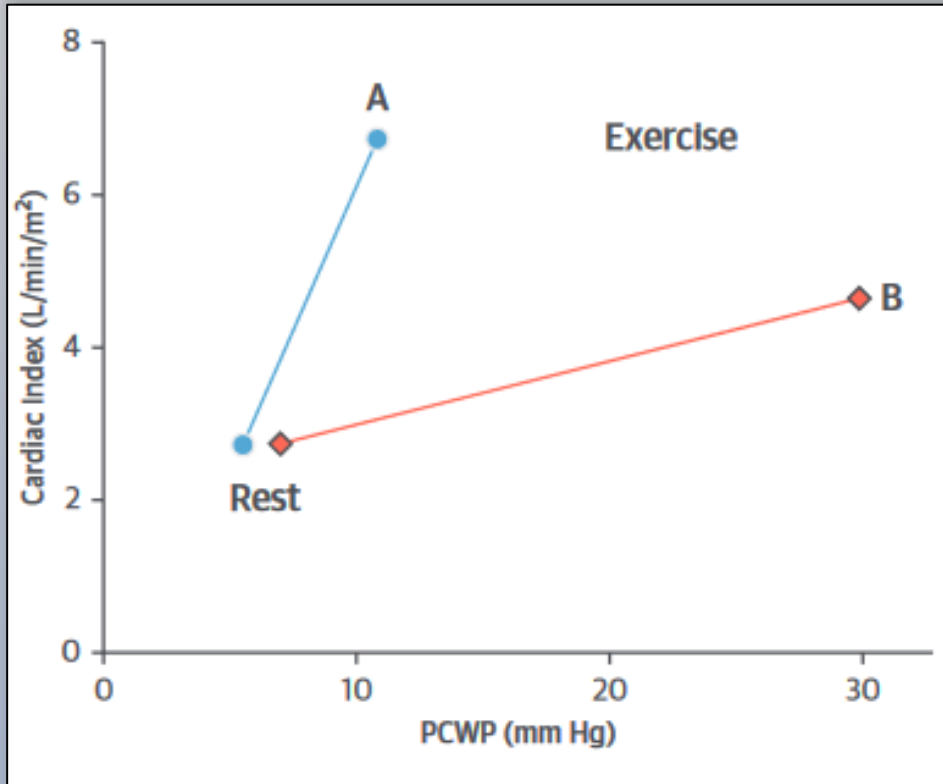
When symptoms appear or when HR 100–110 bpm

Possible continuation of the stress test and acquisition of echocardiography images

Acquisition of echocardiography images

At rest





Changes of cardiac output and pulmonary capillary wedge pressures (PCWP) during exercise. Patients A and B have almost identical left ventricular filling pressures and cardiac index at rest. In Patient A, there is a significant increase in cardiac index with a small change in left ventricular filling pressure (normal response), whereas in Patient B, there is a significant increase in left ventricular filling pressure but smaller increase in cardiac index during exercise.

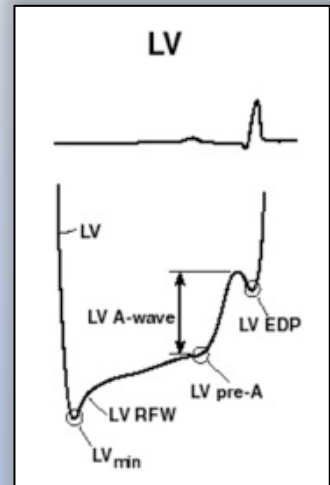
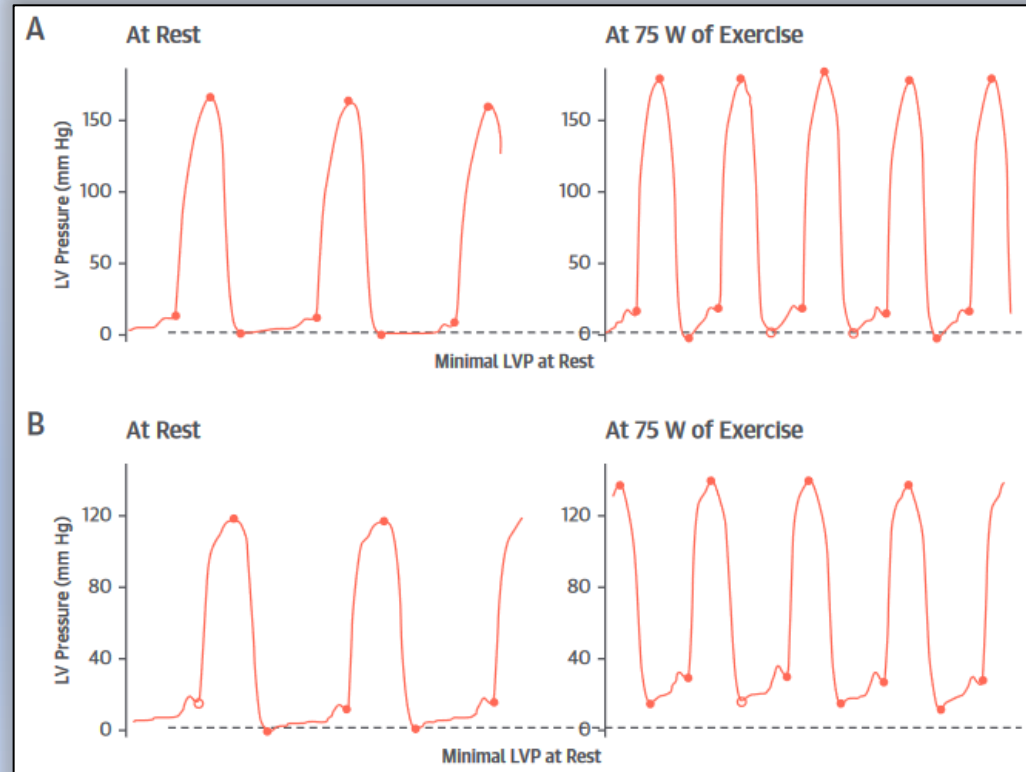
STATE-OF-THE-ART REVIEW

JACC: CARDIOVASCULAR IMAGING
VOL. 13, NO. 1, 2020

Diastolic Stress Test

Invasive and Noninvasive Testing

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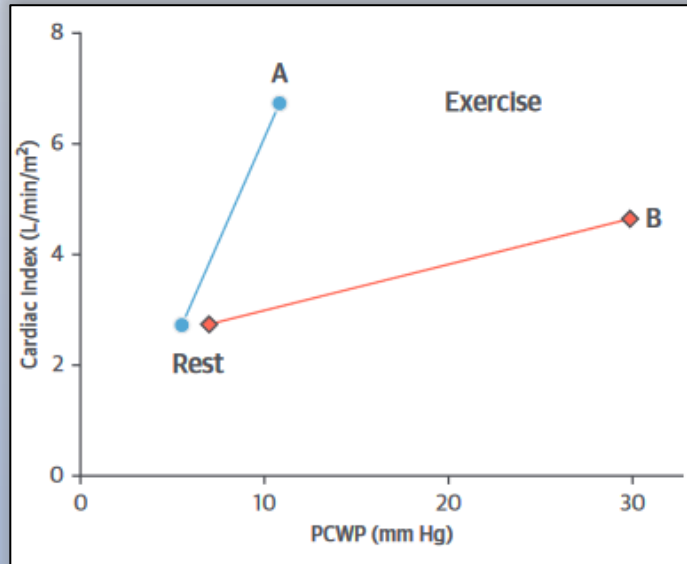
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Circulation

Volume 113, Issue 21, 30 May 2006; Pages 2524-2533
<https://doi.org/10.1161/CIRCULATIONAHA.105.596502>

Enhanced Ventricular Untwisting During Exercise

A Mechanistic Manifestation of Elastic Recoil Described by Doppler Tissue Imaging

Yuichi Notomi, MD, Maureen G. Martin-Miklovic, RDCS, Stephanie J. Orszak, BA, CCRP, Takahiro Shiota, MD, Dimitri Deserranno, PhD, Zoran B. Popovic, MD, Mario J. Garcia, MD, Neil L. Greenberg, PhD, and James D. Thomas, MD

Table 2. Baseline and Exercise Invasive and Noninvasive Hemodynamics

	Baseline		20 W Exercise		Peak Exercise	
	NCD	HFpEF	NCD	HFpEF	NCD	HFpEF
Invasive hemodynamics						
Heart rate, bpm	68±13	67±10	91±14	88±14	121±18	97±15*
Systolic BP, mm Hg	139±24	149±21	167±29	175±26	184±25	185±30
RA pressure, mm Hg	4±2	10±4*	8±3	21±5*	8±4	22±6*
PA mean pressure, mm Hg	16±4	27±8*	25±7	47±10*	27±6	48±8*
PCWP, mm Hg	7±3	17±6*	14±5	31±5*	14±5	34±6*
Cardiac output, L/min	5.2±1.8	5.1±1.2	8.2±1.8	6.8±2.0†	11.8±3.9	8.1±2.8*
Cardiac index, L/min×m ²	2.7±0.8	2.4±0.6	4.3±0.9	3.2±1.0*	6.0±1.7	3.8±1.3*

Circulation

Volume 113, Issue 21, 30 May 2006; Pages 2524-2533
<https://doi.org/10.1161/CIRCULATIONAHA.105.596502>



IMAGING

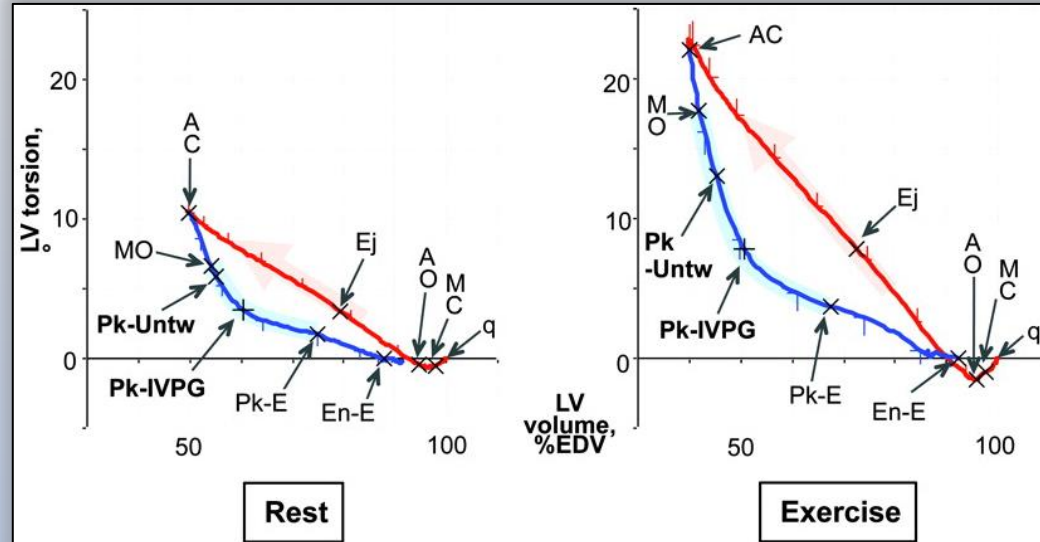
Enhanced Ventricular Untwisting During Exercise

A Mechanistic Manifestation of Elastic Recoil Described by Doppler Tissue Imaging

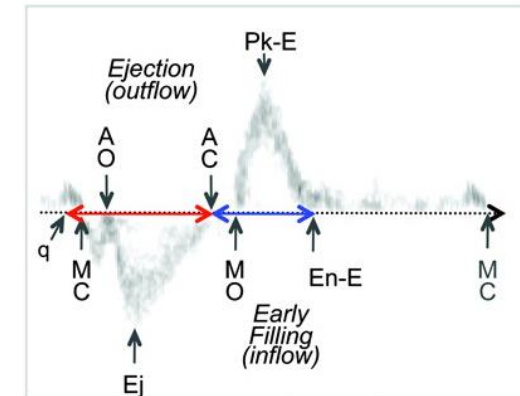
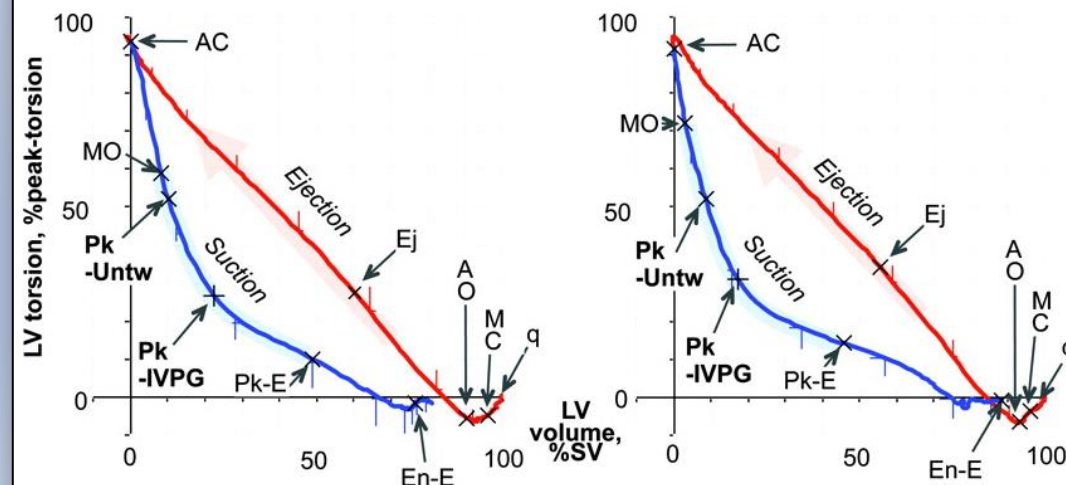
Yuichi Notomi, MD, Maureen G. Martin-Miklovic, RDCS, Stephanie J. Oryszak, BA, CCRP, Takahiro Shiota, MD, Dimitri Deserranno, PhD, Zoran B. Popovic, MD, Mario J. Garcia, MD, Neil L. Greenberg, PhD, and James D. Thomas, MD

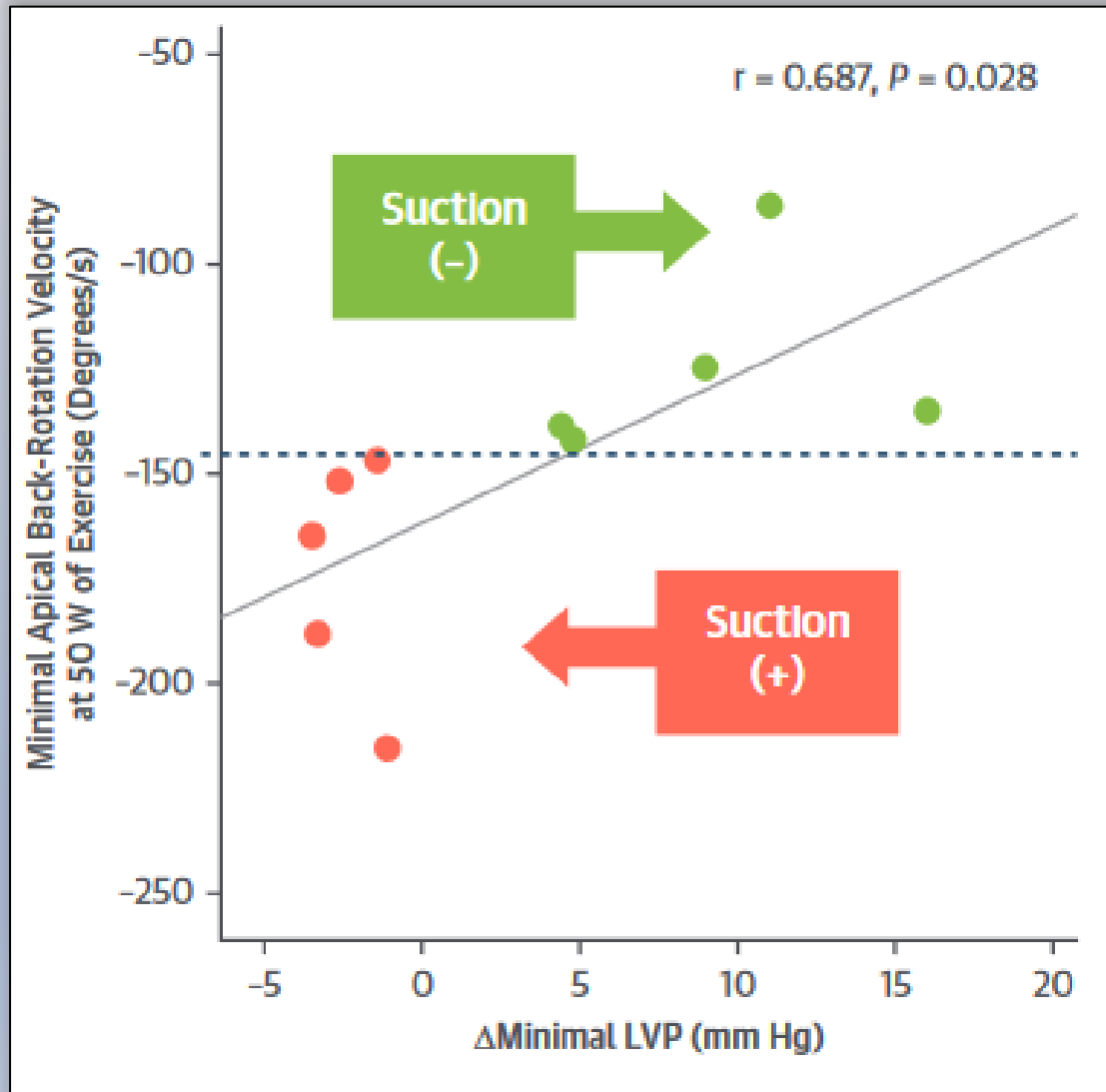
LV torsion and subsequent rapid untwisting appear to be manifestations of elastic recoil, critically linking systolic contraction to diastolic filling.

Systolic Torsion for Diastolic Untwisting & Diastolic Untwisting for LV Suction



LV untwisting appears to be linked temporally with early diastolic base-to-apex pressure gradients, enhanced by exercise, which may assist efficient LV filling.





STATE-OF-THE-ART REVIEW

JACC: CARDIOVASCULAR IMAGING
VOL. 13, NO. 1, 2020

Diastolic Stress Test

Invasive and Noninvasive Testing

Jong-Won Ha, MD, PhD,^a Oyvind S. Andersen, MD,^b Otto A. Smiseth, MD, PhD^b

Patients with a preserved LV suction during exercise showed marked increase in LV untwisting velocity with exercise whereas patients without LV suction during exercise showed minimal increase in LV untwisting velocity with exercise. LVP = left ventricular pressure.

STRESS ΕΧΟ ΠΑΡΑΜΕΤΡΟΙ ΣΧΕΤΙΖΟΜΕΝΟΙ ΜΕ ΜΗΧΑΝΙΣΜΟΥΣ ΔΙΑΣΤΟΛΙΚΗΣ ΔΥΣΛΕΙΤΟΥΡΓΙΑΣ

European Journal of
Heart Failure



European Journal of Heart Failure (2014) 16, 1345–1361
doi:10.1002/ejhf.184

A systematic review of diastolic stress tests in heart failure with preserved ejection fraction, with proposals from the EU-FP7 MEDIA study group

Tamás Erdei, Otto A. Smiseth, Paolo Marino, Alan G. Fraser ✉

Table 4 Possible mechanisms for diastolic dysfunction on exercise, related to diagnostic targets on echocardiography

Possible mechanism	Diagnostic imaging target by echocardiography
Delayed and reduced untwisting	Timing and amplitude and rate of untwisting
Impaired suction	Reduced flow propagation velocity (V_p)
Slow relaxation, reduced early diastolic myocardial functional reserve	Reduced increment in e' ($e'_{\text{exercise}}/e'_{\text{rest}}$)* Prolonged isovolumic relaxation time (IVRT) Prolonged deceleration time (DT) of mitral inflow
Reduced LV compliance during stress (increased regional myocardial stiffness)	Comparison of antegrade mitral flow and retrograde flow in pulmonary veins during atrial contraction ($A_{r_d} - A_d$)
Increased LV mean filling pressure	Increased rise in E/e' ($E/e'_{\text{exercise}}/E/e'_{\text{rest}}$)* Changes in E/V_p
Reduced longitudinal systolic myocardial functional reserve	Reduced increment in s' ($s'_{\text{exercise}}/s'_{\text{rest}}$)*

*Recommended by the EU-FP7 MEDIA study group.

Diastolic SE performed for the assessment of dyspnoea, breathlessness, or exertional fatigue.

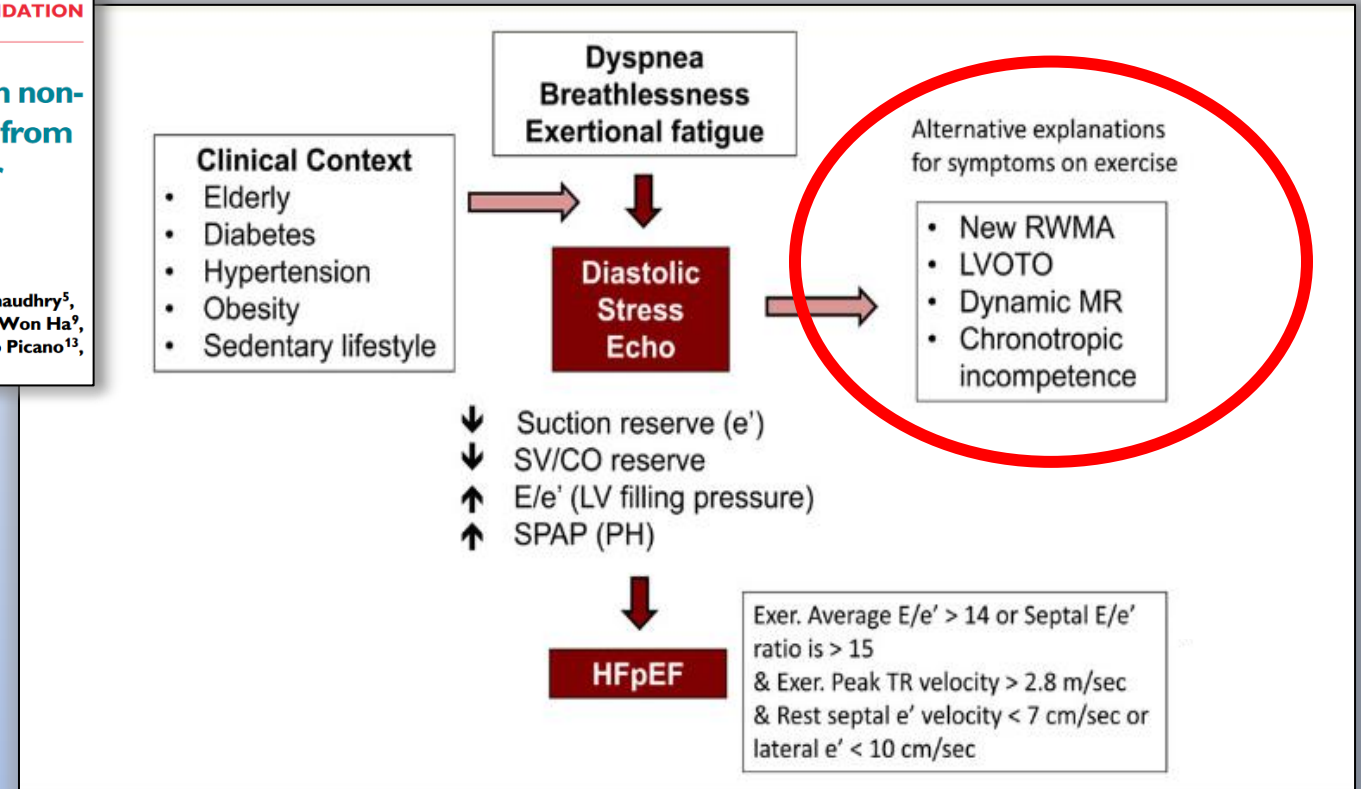


European Heart Journal – Cardiovascular Imaging (2016) 17, 1191–1229
doi:10.1093/ehjci/jew190

EACVI/ASE RECOMMENDATION

The clinical use of stress echocardiography in non-ischaemic heart disease: recommendations from the European Association of Cardiovascular Imaging and the American Society of Echocardiography

Patrizio Lancellotti^{1,2*}, Patricia A. Pellikka³, Werner Budts⁴, Farooq A. Chaudhry⁵, Erwan Donal⁶, Raluca Dulgheru¹, Thor Edvardsen⁷, Madalina Garbi⁸, Jong-Won Ha⁹, Garvan C. Kane³, Joe Kreeger¹⁰, Luc Mertens¹¹, Philippe Pibarot¹², Eugenio Picano¹³, Thomas Ryan¹⁴, Jeane M. Tsutsui¹⁵, and Albert Varga¹⁶



Review > Hellenic J Cardiol. 2022 Mar-Apr;64:30-57. doi: 10.1016/j.hjc.2021.07.006.
Epub 2021 Jul 28.

Updated knowledge and practical implementations of stress echocardiography in ischemic and non-ischemic cardiac diseases: An expert consensus of the Working Group of Echocardiography of the Hellenic Society of Cardiology

Nikolaos P E Kadoglou¹, Constantinos H Papadopoulos², Konstantinos G Papadopoulos³,

DSTE should not only focus on diastolic function parameters, but in parallel, evaluate all the dynamic components of LV function (WMA, valvular diseases, etc), RV function (TR Vmax, tricuspid annular plane systolic excursion - TAPSE, S' wave in Tissue Doppler imaging), the chronotropic and blood pressure response, the achieved work-load, and the exercise capacity. Those findings are associated with unfavorable outcomes if combined with elevated LVFP.

ASE/EACVI GUIDELINES AND STANDARDS

(J Am Soc Echocardiogr 2016;29:277-314.)

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

Sherif F. Nagueh, Chair, MD, FASE,¹ Otto A. Smiseth, Co-Chair, MD, PhD,² Christopher P. Appleton, MD,¹

Circulation: Cardiovascular Imaging

Volume 10, Issue 9, September 2017

<https://doi.org/10.1161/CIRCIMAGING.117.006547>



Cardiac Imaging in Patients With Heart Failure and Preserved Ejection Fraction

Sherif F. Nagueh, MD, Su Min Chang, MD, Faisal Nabi, MD, Dipan J. Shah, MD, and Jerry D. Estep, MD

The way of interpreting results of diastolic exercise echocardiography proposed by the American Society of Echocardiography and the European Association of Cardiovascular Imaging from 2016

Parameter	Normal result (both conditions must be fulfilled together)	Undiagnostic result	Abnormal result* (both conditions must be fulfilled together)
E/e' (or E/e' med)	< 10 (10)	10-14 (15)	> 14 (15)
TRV [m/s]	< 2.8	Any	> 2.8

*In addition, in a resting test, the speed of e' med < 7 cm/s or, if only e' lat has been registered, it must be < 10 cm/s; E — early diastolic velocity of mitral inflow wave; e' — averaged value of early diastolic lateral and medial mitral ring velocity; e' med — value of early diastolic velocity of the medial part of the mitral ring (used for interpretation when the velocity of both parts of the mitral ring cannot be measured); e' lat — value of early diastolic lateral velocity of the mitral ring; TRV — maximum tricuspid regurgitation wave velocity expressed in meters per second

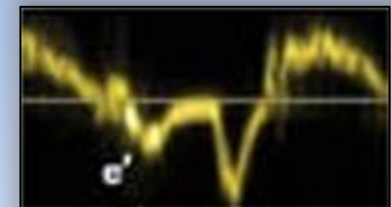
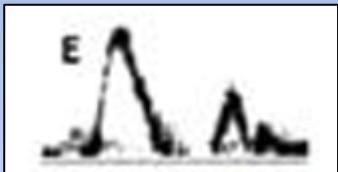
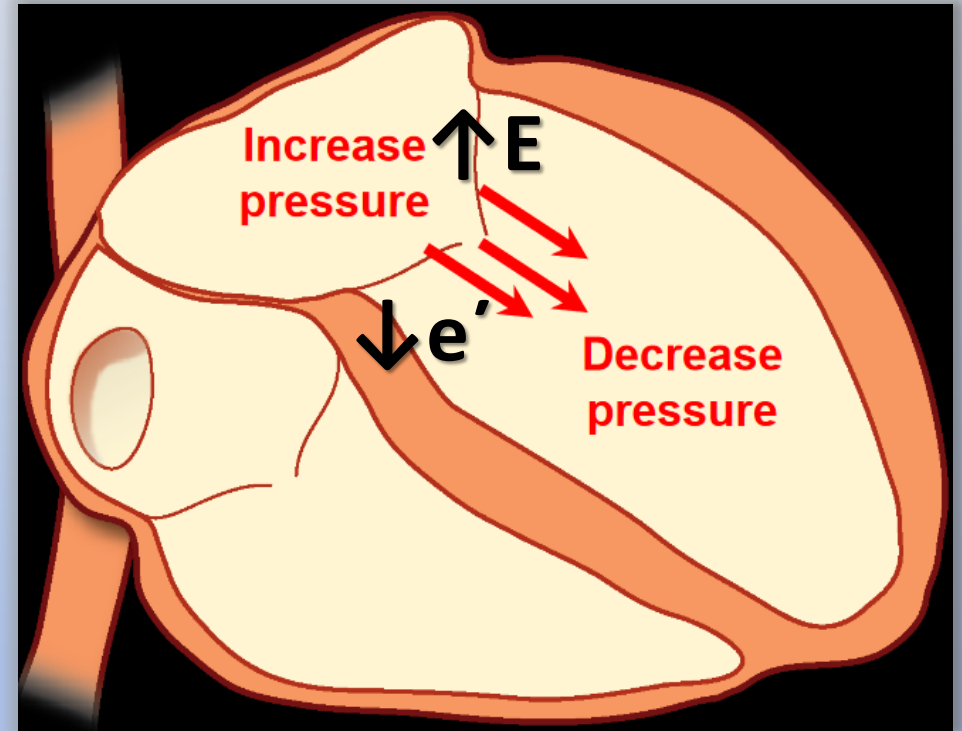
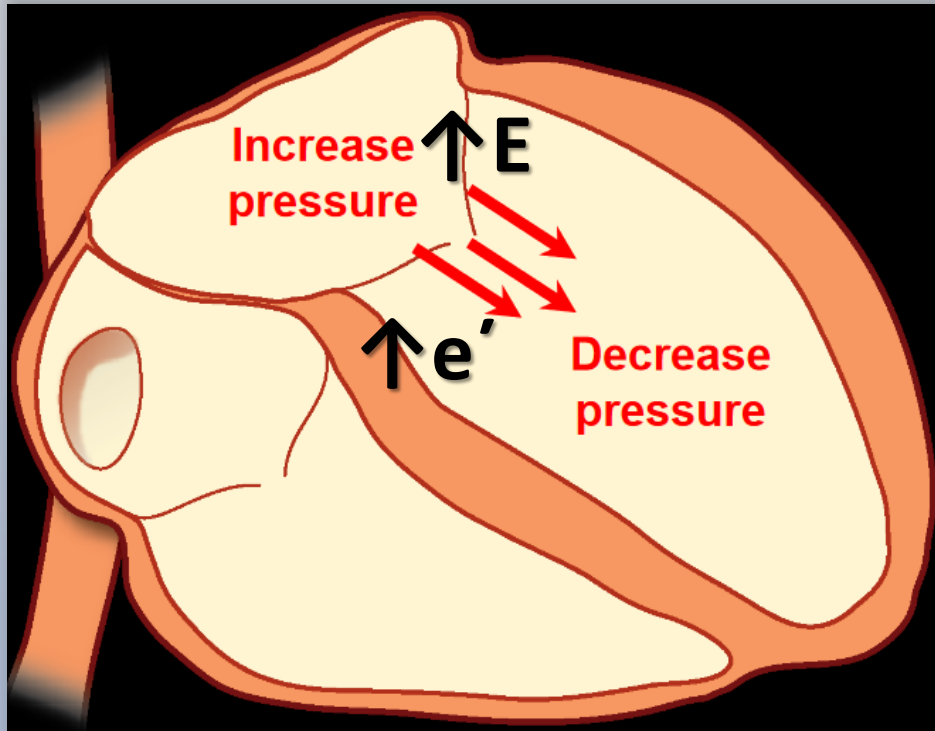
- **Diastolic exercise echocardiography should be considered abnormal if average E/e' ratio at peak stress increases to ≥ 15 , with or without a peak TR velocity > 3.4 m/s.**

- **An increase only in TR velocity should not be used to diagnose HFpEF because it might be caused simply by a normal hyperdynamic response to exercise (with increased pulmonary blood flow) in the absence of LV diastolic dysfunction.**

DIASTOLIC STRESS E/e' (1)

Healthy heart
normal parameters of diastolic function

example of diastolic function disorders



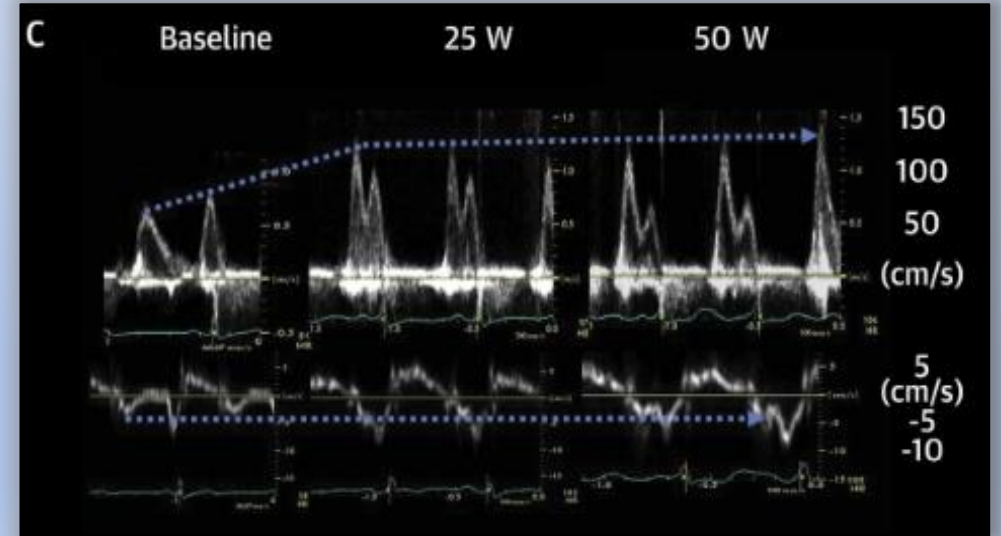
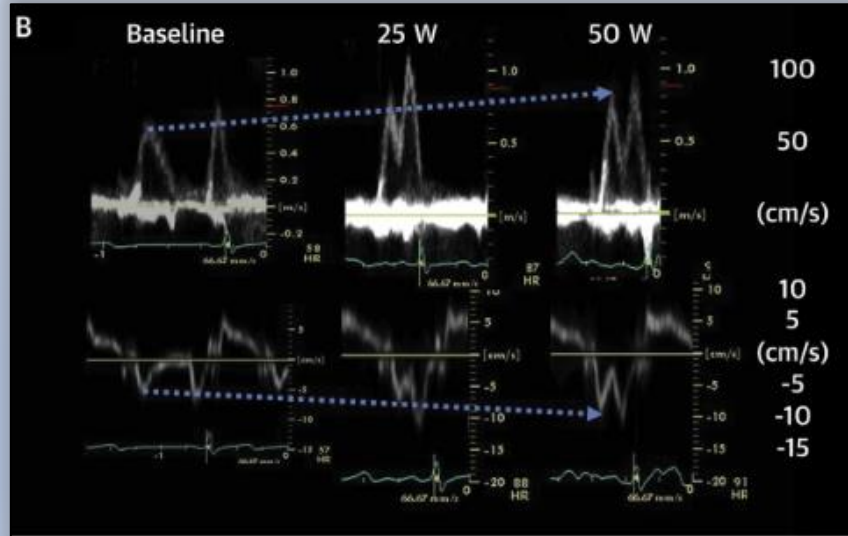
STATE-OF-THE-ART REVIEW

JACC: CARDIOVASCULAR IMAGING
 VOL. 13, NO. 1, 2020

Diastolic Stress Test

Invasive and Noninvasive Testing

Jong-Won Ha, MD, PhD,^a Oyvind S. Andersen, MD,^b Otto A. Smiseth, MD, PhD^b



In Patient B, there is a concordant rise in both mitral E velocity and mitral annular e' velocity with exercise, without an overall change in mitral E/e' ratio. In Patient C, there is an increase in mitral E velocity but minimal change in e' with exercise, resulting in increased E/e' , suggestive of elevated left ventricular filling pressures with exercise.

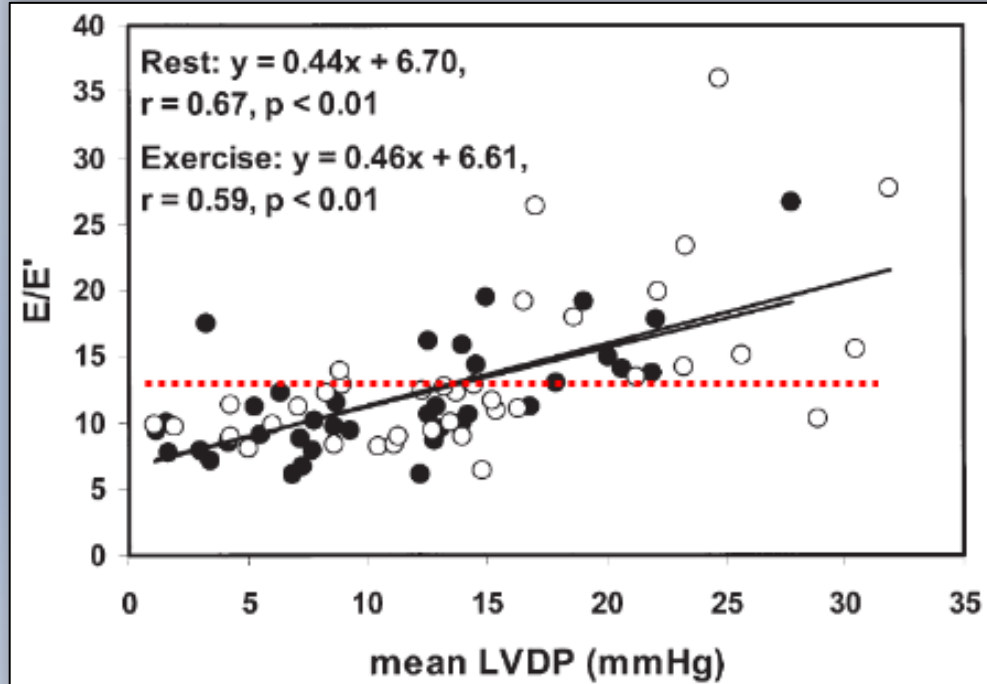
DIASTOLIC STRESS E/e' (3)

> *J Am Coll Cardiol.* 2006 May 2;47(9):1891-900. doi: 10.1016/j.jacc.2006.02.042. Epub 2006 Apr 3.

Diastolic stress echocardiography: hemodynamic validation and clinical significance of estimation of ventricular filling pressure with exercise

Malcolm I Burgess¹, Carly Jenkins, James E Sharman, Thomas H Marwick

Conclusions: The ratio of early diastolic transmitral velocity to early diastolic tissue velocity correlates with invasively measured LVDP during exercise. It can be used to reliably identify patients with elevated LVDP during exercise and reduced exercise capacity.

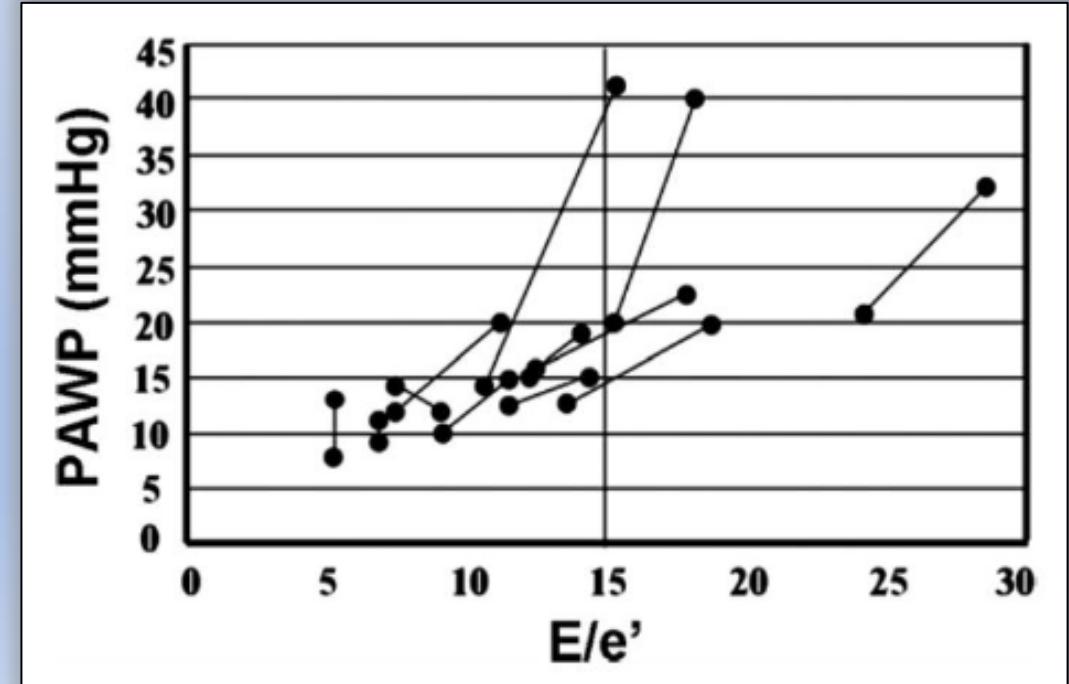


> *J Am Soc Echocardiogr.* 2007 May;20(5):477-9. doi: 10.1016/j.echo.2006.10.005.

Estimation of left ventricular filling pressure with exercise by Doppler echocardiography in patients with normal systolic function: a simultaneous echocardiographic-cardiac catheterization study

Deepak R Talreja¹, Rick A Nishimura, Jae K Oh

Conclusion: Noninvasively obtained Doppler of mitral and mitral annulus velocities provides a reliable estimation of PAWP not only at baseline, but also with exercise. Specifically, an E/e' ratio of greater than 15 during exercise is associated with a significantly elevated PAWP of greater than 20 mm Hg.



LIMITATIONS



Circulation

Volume 135, Issue 9, 28 February 2017; Pages 825-838
<https://doi.org/10.1161/CIRCULATIONAHA.116.024822>



ORIGINAL RESEARCH ARTICLE

Role of Diastolic Stress Testing in the Evaluation for Heart Failure With Preserved Ejection Fraction

A Simultaneous Invasive-Echocardiographic Study

Masaru Obokata, MD, PhD, Garvan C. Kane, MD, PhD, Yogesh N. V. Reddy, MD, Thomas P. Olson, PhD, Vojtech Melenovsky, MD, PhD, and Barry A. Borlaug, MD

- *It was reported that E/e' was not measurable in about 10% of subjects during submaximal exercise (20 W) and in about 20% of HFpEF patients during peak exercise .*
- *TR velocity was measurable in only 50%;*
- *About 20% of controls were considered to have false-positive tests.*

Low-Level Diastolic SE (E/e'_{20W})

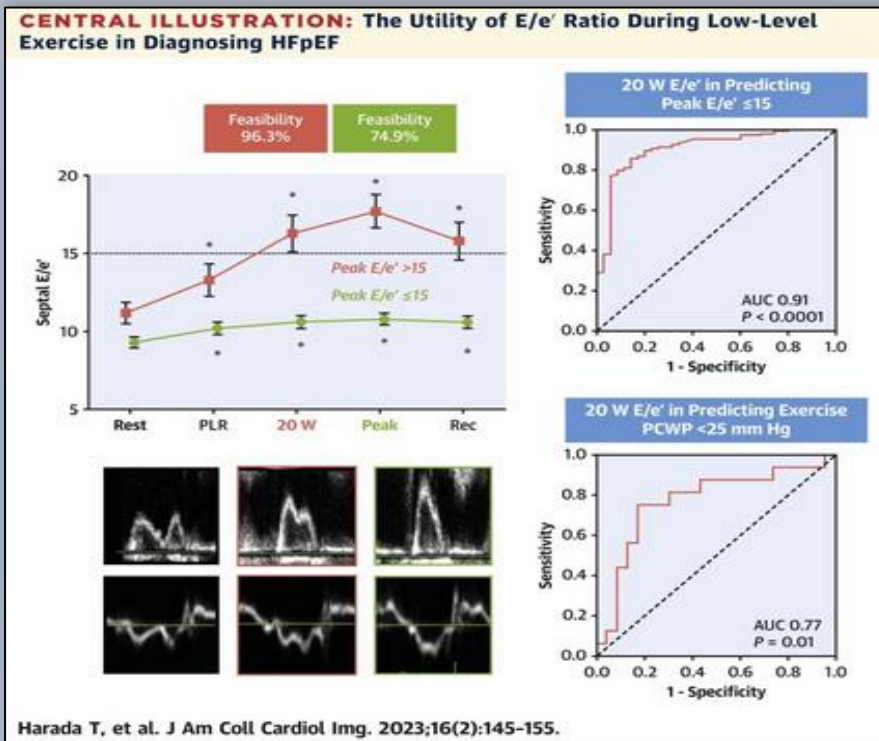
JACC: Cardiovascular Imaging
Volume 16, Issue 2, February 2023, Pages 145-155

ELSEVIER

Original Research

Utility of E/e' Ratio During Low-Level Exercise to Diagnose Heart Failure With Preserved Ejection Fraction

Tomonari Harada MD, PhD,^a Masaru Obokata MD, PhD,^a Kazuki Kagami MD,^{a,b},
Hidemi Sorimachi MD, PhD,^a Toshimitsu Kato MD, PhD,^a Noriaki Takama MD, PhD,^a,
Naoki Wada MD, PhD,^c Hideki Ishii MD, PhD,^a



Results

The feasibility of the E/e' ratio decreased from 100% at rest to 96.3% during 20-W exercise and 74.9% during peak exercise caused by E-A fusion. In patients with $E/e'_{peak} > 15$, there was an increase in E/e' ratio from rest to 20-W exercise (11.2 ± 2.1 to 16.3 ± 3.5 ; $P < 0.0001$), but it did not change significantly from 20-W exercise to peak exercise ($P = 0.12$). E/e'_{20W} predicted $E/e'_{peak} \leq 15$ (AUC: 0.91; $P < 0.0001$) with the cutoff value of ≤ 12.4 showing high specificity (94%) and positive predictive value (98%). During 20-W exercise, 93% of the HFpEF patients developed $PCWP \geq 25$ mmHg. E/e'_{20W} predicted normal PCWP during exercise (AUC: 0.77; $P = 0.01$) with the cutoff value of ≤ 12.4 showing high specificity (83%).

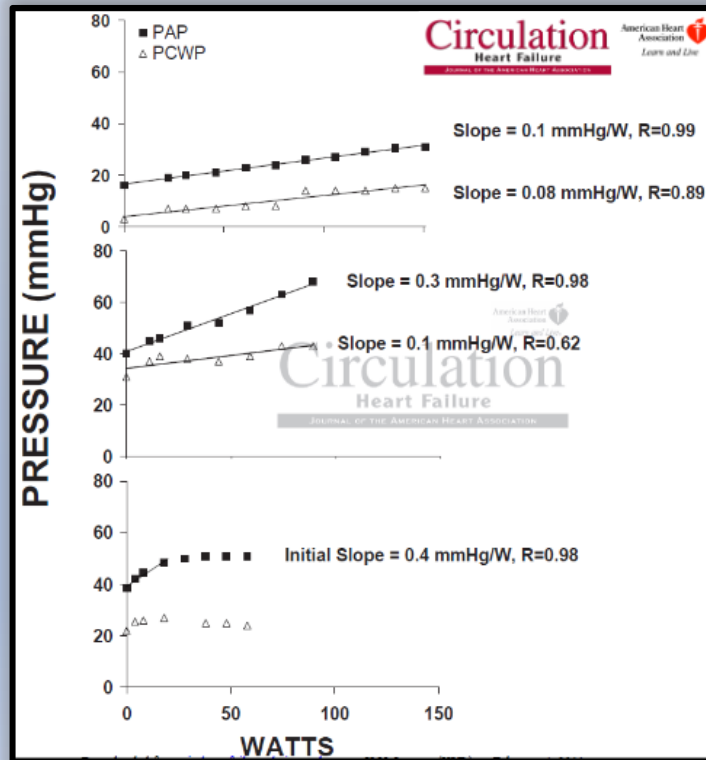
Conclusions

E/e' ratio during low-level exercise is highly feasible and predicts normal E/e' ratio or PCWP during peak exercise with high specificity. These data suggest that E/e'_{20W} could be used as an alternative to the peak exercise value to rule out HFpEF in patients with dyspnea.

> *Circ Heart Fail.* 2011 May;4(3):276-85. doi: 10.1161/CIRCHEARTFAILURE.110.959437.
Epub 2011 Feb 3.

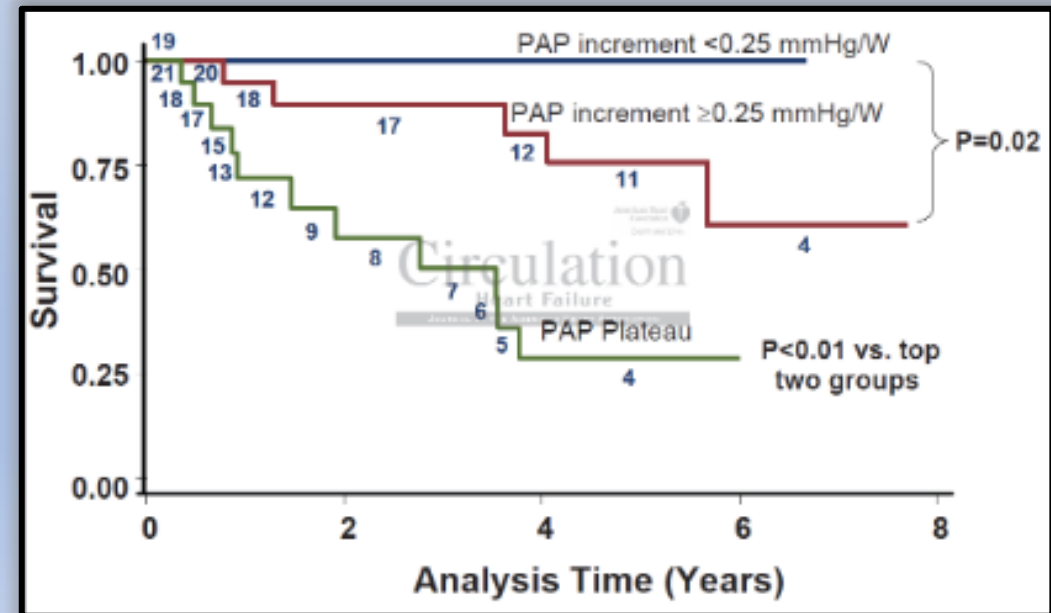
Pulmonary vascular response patterns during exercise in left ventricular systolic dysfunction predict exercise capacity and outcomes

Gregory D Lewis¹, Ryan M Murphy, Ravi V Shah, Paul P Pappagianopoulos, Rajeev Malhotra, Kenneth D Bloch, David M Systrom, Marc J Semigran



Failure to increase PAP with exercise is associated with a poor prognosis

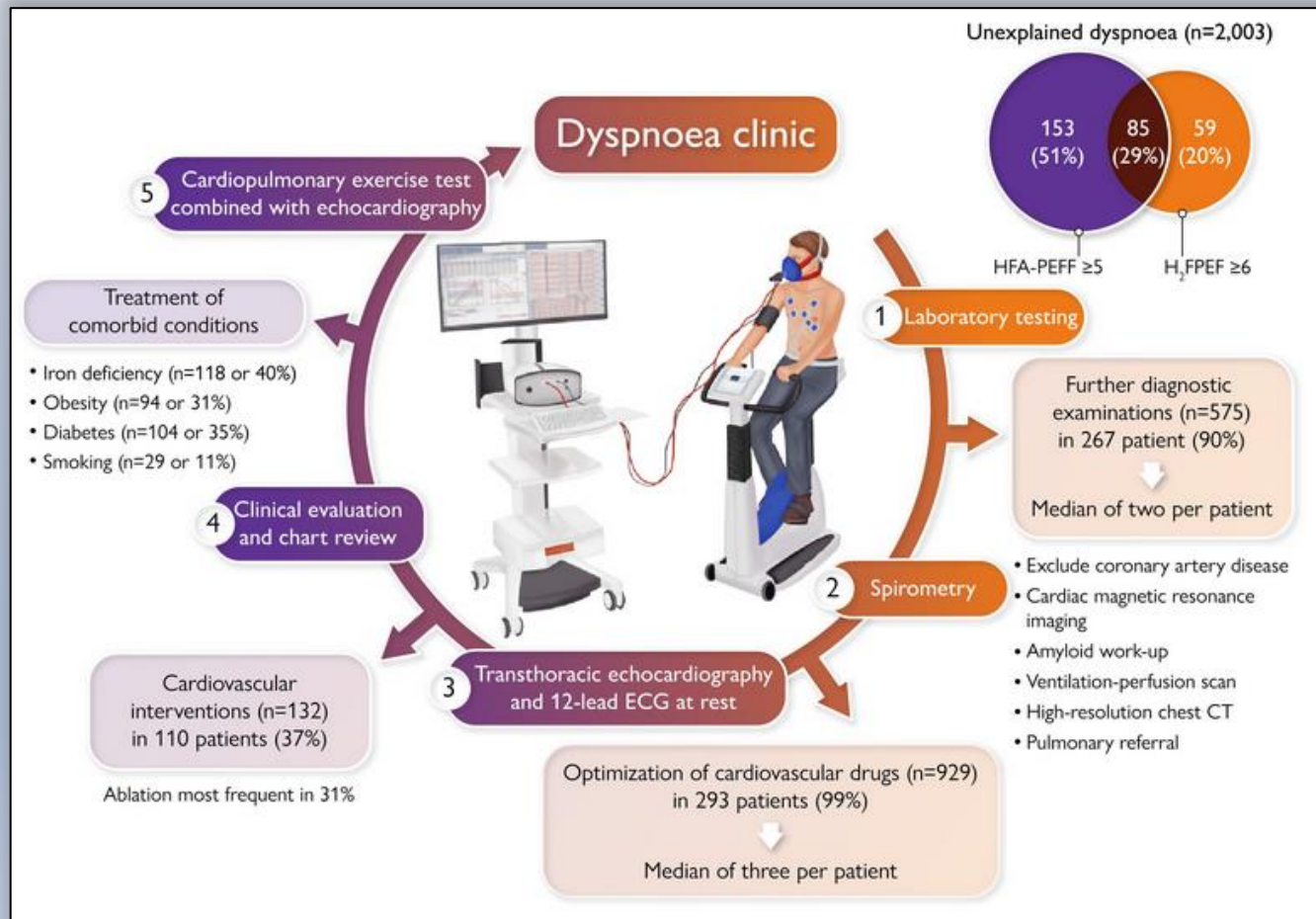
A steep increment in PAP during exercise and failure to augment PAP throughout exercise are associated with decreased exercise capacity and survival in patients with LVSD.



DIASTOLIC STRESS ECHO – ΜΕΡΟΣ ΟΛΙΣΤΙΚΗΣ ΑΝΤΙΜΕΤΩΠΙΣΗΣ ΤΗΣ ΗFpEF

Key Question

Which haemodynamic and metabolic alterations are revealed when systematic assessment including cardiopulmonary exercise testing with echocardiography (CPETecho) is performed in patients with heart failure and preserved ejection fraction (HFpEF) within a multidisciplinary, dedicated dyspnoea clinic?



JOURNAL ARTICLE

European Heart Journal

Heart failure with preserved ejection fraction: relevance of a dedicated dyspnoea clinic

Get access >

Jan Verwerft, Lucie Soens, Joke Wynants, Marc Meysman, Siddharth Jogani, Danielle Plein, Sarah Stroobants, Lieven Herbots, Frederik H Verbrugge ✉

European Heart Journal, ehad141, <https://doi.org/10.1093/eurheartj/ehad141>

Published: 16 March 2023 Article history ▼







Consecutive patients (n = 297), referred to a dedicated dyspnoea clinic using a standardized workup including CPETecho, with HFpEF diagnosed through a H₂FPEF score ≥6 or HFA-PEFF score ≥5, were evaluated.

HFpEF – ΕΝΑ ΣΥΝΘΕΤΟ ΑΙΜΟΔΥΝΑΜΙΚΟ & ΜΕΤΑΒΟΛΙΚΟ ΠΡΟΒΛΗΜΑ

Take Home Message

Holistic work-up of HFpEF patients within a multidisciplinary, dedicated dyspnoea clinic, including systematic implementation of CPETech reveals various hemodynamic and metabolic alterations, leading to further diagnostic testing and potential treatment changes in the majority of cases.

Impaired exercise reserve across multiple organs in HFpEF

	Physiologic measure	Select HFpEF studies	Verwerft et al. [Dyspnoea + high HFpEF scores]
 Exercise intolerance	Peak VO ₂	Average 14.9 ml/kg/min ^a	13.6±4.7 ml/kg/min
 Pulmonary function	Lung function testing, breathing reserve, VE/VCO ₂ slope	94% at least 1 abnormality in lung function testing ^a	39% ventilatory limitation
 Pulmonary vascular function	Rest PH, exercise PH	>50% rest PH ^a	65% exercise PH
 Cardiac function	Systolic reserve (SV, CO)	28% had fall in SVI with exercise ¹³	73% impaired SV reserve
	Diastolic reserve (PCWP)	Diagnostic for exercise HFpEF	64% impaired diastolic reserve
	Chronotropic reserve (HR)	~56% had chronotropic incompetence ¹³	72% chronotropic incompetence
 Peripheral vascular function	Arterial stiffness (VA coupling, stiffness)	Multiple measures*	Not assessed
	Endothelial dysfunction	42% prevalence by reactive hyperaemia index ¹⁴	Not assessed
 Skeletal muscle	Peripheral O ₂ extraction	Predominant limiting factor in up to 40% of patients ¹⁵	40% impaired O ₂ extraction

*no accepted clinical cutpoints to define abnormal

JOURNAL ARTICLE

European Heart Journal

Heart failure with preserved ejection fraction: relevance of a dedicated dyspnoea clinic

Get access >

Jan Verwerft, Lucie Soens, Joke Wynants, Marc Meysman, Siddharth Jogani, Danielle Plein, Sarah Stroobants, Lieven Herbots, Frederik H Verbrugge ✉

European Heart Journal, ehad141, <https://doi.org/10.1093/eurheartj/ehad141>

Published: 16 March 2023 Article history ▾

A median of four haemodynamic/metabolic alterations was uncovered per patient: impaired stroke volume reserve (73%), impaired chronotropic reserve (72%), exercise pulmonary hypertension (65%), and impaired diastolic reserve (64%) were the most frequent cardiac alterations. Impaired peripheral oxygen extraction and a ventilatory limitation were present in 40% and 39%, respectively. In 267 patients (90%), 575 further diagnostic examinations were recommended (median of two tests per patient). Cardiac magnetic resonance imaging, coronary or amyloidosis workup, ventilation–perfusion scanning, and pulmonology referral were each recommended in approximately one out of three patients. In 293 patients (99%), 929 cardiovascular drug optimizations were performed (median of 3 modifications per patient). In 110 patients (37%), 132 cardiovascular interventions were performed, with ablation as the most frequent procedure.

- ¹/8** . ΔΙΕΝΕΡΓΕΙΑ DSTE ΣΕ ΑΣΘΕΝΕΙΣ ΜΕ ΑΚΑΘΟΡΙΣΤΗ ΔΙΑΣΤΟΛΙΚΗ ΛΕΙΤΟΥΡΓΙΑ, ΥΠΟΠΤΟΥΣ ΓΙΑ ΗFrEF, ΜΕ ΣΥΜΠΤΩΜΑΤΑ ΕΝΔΕΙΚΤΙΚΑ ΚΑΡΔΙΑΚΗΣ ΑΝΕΠΑΡΚΕΙΑΣ ΚΑΙ ΚΥΡΙΩΣ ΔΥΣΠΝΟΙΑ ΚΟΠΩΣΕΩΣ.
- ²/8** . DSTE ΣΤΟ ΠΛΑΙΣΙΟ ΔΙΑΓΝΩΣΗΣ, ΕΚΤΙΜΗΣΗΣ ΣΟΒΑΡΟΤΗΤΑΣ, ΠΡΟΓΝΩΣΗΣ, ΔΙΕΡΕΥΝΗΣΗΣ ΓΙΑ ΠΙΘΑΝΟ ΘΕΡΑΠΕΥΤΙΚΟ ΟΦΕΛΟΣ.
- ³/8** . Η ΧΡΗΣΗ ΤΩΝ ΠΑΡΑΜΕΤΡΙΚΩΝ SCORE Η2FrEF & HFrEF ΣΤΟ ΔΙΑΓΝΩΣΤΙΚΟ ΑΛΓΟΡΙΘΜΟ ΤΩΝ ΑΣΘΕΝΩΝ ΜΕ ΑΝΕΞΗΓΗΤΗ ΔΥΣΠΝΟΙΑ ΣΥΜΒΑΤΗ ΜΕ ΗFrEF, ΒΟΗΘΑΕΙ ΣΤΗ ΛΗΨΗ ΑΠΟΦΑΣΗΣ ΓΙΑ ΔΙΕΝΕΡΓΕΙΑ DSTE.
- ⁴/8** . ΕΡΓΟΜΕΤΡΙΚΟ ΠΟΔΗΛΑΤΟ (SEMI-SUPINE BICYCLE) ΩΣ ΜΕΘΟΔΟΣ ΚΟΠΩΣΗΣ, ΜΕ ΤΟ ΠΡΩΤΟΚΟΛΛΟ Cardiff-MEDIA ΝΑ ΠΡΟΚΡΙΝΕΤΑΙ ΓΙΑ ΤΑ ΦΙΛΙΚΟΤΕΡΑ ΧΑΡΑΚΤΗΡΙΣΤΙΚΑ ΕΦΑΡΜΟΓΗΣ ΤΟΥ (starting at 15 Watt and with increments of 5 Watt/min, to a submaximal target heart rate of 100–110/min or until the patient develops limiting symptoms).
- ⁵/8** . ΣΥΜΠΕΡΑΣΜΑΤΙΚΑ ΣΤΟ DSTE ΔΙΑΓΝΩΣΗ ΔΙΑΣΤΟΛΙΚΗΣ ΔΥΣΛΕΙΤΟΥΡΓΙΑΣ ΠΡΕΠΕΙ ΝΑ ΙΚΑΝΟΠΟΙΕΙ ΟΛΑ ΤΑ ΠΡΑΚΑΤΩ ΚΡΙΤΗΤΡΙΑ: Peak average $E/e' > 14$ **OR** Peak Septal $E/e' > 15$ **AND** TR $V_{max} > 2,8$ m/s ΜΕ ΤΙΜΕΣ ΗΡΕΜΙΑΣ Septal $e' < 7$ cm/s **OR** Lateral $e' < 10$ cm/s.
- ⁶/8** . ΜΕΛΕΤΑΤΑΙ Ο ΡΟΛΟΣ ΝΕΩΝ ΔΕΙΚΤΩΝ ΚΑΤΑ ΤΟ DSTE (π.χ. Low-Level Diastolic SE E/e'_{20w} , Global LA Strain or LA Conduit Strain), ΚΑΘΩΣ ΚΑΙ Ο ΡΟΛΟΣ ΤΟΥ 3D ECHO ΚΑΤΑ ΤΗ DSTE (Pressure—Volume Loops, SV).
- ⁷/8** . ΚΑΤΑ ΤΟ DSTE ΝΑ ΓΙΝΕΤΑΙ ΕΚΤΙΜΗΣΗ ΟΛΩΝ ΤΩΝ ΔΥΝΑΜΙΚΩΝ ΠΑΡΑΜΕΤΡΩΝ ΛΕΙΤΟΥΡΓΙΑΣ ΤΗΣ LV/RV, ΤΟΥ ΕΠΙΤΕΥΧΘΕΝΤΟΣ ΕΡΓΟΥ ΚΑΙ ΤΗΣ ΓΕΝΙΚΟΤΕΡΗΣ ΙΚΑΝΟΤΗΤΑΣ ΑΣΚΗΣΗΣ / ΠΙΘΑΝΗ ΑΝΑΔΕΙΞΗ ΕΝΑΛΛΑΚΤΙΚΩΝ ΜΗΧΑΝΙΣΜΩΝ ΓΙΑ ΕΜΦΑΝΙΣΗ ΔΥΣΠΝΟΙΑΣ (π.χ. ΤΜΗΜΑΤΙΚΕΣ ΔΙΑΤΑΡΑΧΕΣ ΤΟΙΧΩΜΑΤΙΚΗΣ ΚΙΝΗΤΙΚΟΤΗΤΑΣ, LVOTO, ΔΥΝΑΜΙΚΗ ΑΝΕΠΑΡΚΕΙΑ ΜΙΤΡΟΕΙΔΙΚΗΣ ΒΑΛΒΙΔΑΣ, ΕΚΠΤΩΣΗ ΤΗΣ ΧΡΟΝΟΤΡΟΠΗΣ ΕΦΕΔΡΕΙΑΣ, ΠΑΘΟΛΟΓΙΚΗ ΑΠΑΝΤΗΣΗ ΤΗΣ ΑΡΤΗΡΙΑΚΗΣ ΠΙΕΣΗΣ).
- ⁸/8** . DSTE ΒΗΜΑ ΤΗΣ ΟΛΙΣΤΙΚΗΣ ΑΝΤΙΜΕΤΩΠΙΣΗΣ ΑΣΘΕΝΟΥΣ ΜΕ ΑΝΕΞΗΓΗΤΗ ΔΥΣΠΝΟΙΑ ΚΑΙ ΗFrEF – ΕΡΓΑΛΕΙΟ ΓΙΑ ΤΗΝ “ΚΛΙΝΙΚΗ ΔΥΣΠΝΟΙΑΣ” ΣΤΟ ΠΛΑΙΣΙΟ ΕΚΤΙΜΗΣΗΣ ΜΕ CRET (CARDIOPULMONARY ECHOCHARDIOGRAPHY EXERCISE TEST).



**21ο ΠΑΝΕΛΛΗΝΙΟ ΚΑΡΔΙΟΛΟΓΙΚΟ ΣΥΝΕΔΡΙΟ
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ΔΙΟΡΓΑΝΩΣΗ: ΚΑΡΔΙΟΛΟΓΙΚΗ ΕΤΑΙΡΕΙΑ ΒΟΡΕΙΟΥ ΕΛΛΑΔΟΣ

**ΕΥΧΑΡΙΣΤΩ
ΓΙΑ ΤΗΝ ΠΡΟΣΟΧΗ ΣΑΣ**

