European Heart Journal Supplements (2019) **21** (Supplement M), M9-M12
The Heart of the Matter
doi:10.1093/eurheartj/suz216

ESC
European Society
of Cardiology

Monitoring functional capacity in heart failure

Massimo F. Piepoli[1]*, Ilaria Spoletini[2], and Giuseppe Rosano[2]

[1]*Heart Failure Unit, Guglielmo da Saliceto Hospital, Cantone del Cristo, 29121 Piacenza, Italy; and*
[2]*Department of Medical Sciences, Centre for Clinical and Basic Research, IRCCS San Raffaele Pisana, Rome, Italy*

KEYWORDS
Heart failure;
Monitoring;
Functional capacity;
Exercise test

This document reflects the key points of a consensus meeting of the Heart Failure Association of European Society of Cardiology (ESC) held to provide an overview the role of physiological monitoring in the complex multimorbid heart failure (HF) patient. This article reviews assessments of the functional ability of patients with HF. The gold standard measurement of cardiovascular functional capacity is peak oxygen consumption obtained from a cardiopulmonary exercise test. The 6-min walk test provides an indirect measure of cardiovascular functional capacity. Muscular functional capacity is assessed using either a 1−repetition maximum test of the upper and lower body or other methods, such as handgrip measurement. The short physical performance battery may provide a helpful, indirect indication of muscular functional capacity.

Introduction

One of the hallmark features of heart failure (HF) is exercise intolerance, which is accompanied by symptoms of fatigue and shortness of breath.[1,2] As the disease progresses, patients experience a downward spiral as these symptoms typically result in reduced physical activity, which leads to progressively worsening exercise intolerance.[3,4] Typically, patients with HF are faced with what can be termed a functional disability.[5-7] Often, their reduced functional abilities restrict or may even prevent them from performing occupational tasks, which may result in loss of work.[8] Additionally, it is well known that HF patients experience impairment in the ability to carry out activities of daily living and suffer from an impaired quality of life.[9-11]

Cardiopulmonary exercise testing

The gold standard method for assessing cardiovascular functional capacity is measurement of oxygen consumption (VO2) during a maximal exercise test.[12-14] This procedure is known as cardiopulmonary exercise testing (CPET).[15-17] The principal outcome variable is maximal or peak oxygen VO2 ($VO2_{max}$ or $VO2_{peak}$). Historically, VO2max is used when the measurement methodology includes determination of a plateau in VO2 measurement values during the last work rate. In clinical practice of HF, the $VO2_{peak}$ is measured as the highest VO2 value, expressed as millilitres of oxygen per kilogram of body weight per minute (mLO2 kg^{-1} min^{-1}) during the exercise test.[18] Recent reports from the Heart Failure Association of the European Society of Cardiology (ESC)[19] provides a stratification approach for diagnosis and prognosis of patients with HF.[20] The key CPET measurements, all clearly defined in the report, included in the stratification are the slope of minute ventilation (VE) relative to carbon dioxide production (VCO2; VE/VCO2 slope); peak VO2; exercise oscillatory ventilation; and the change in the partial pressure of carbon.[21-24] The stratification also includes consideration of the blood pressure and electrocardiographic response during the exercise test.[25-27]

Today CPET is used in broader patient populations, including women, the elderly, patients with comorbidities, those with preserved ejection fraction, or left ventricular assistance device recipients, i.e. individuals with different responses to incremental exercise and markedly different prognosis.[28-30] In addition, the diagnostic and prognostic utility of symptom-limited CPET parameters derived from submaximal tests has been studied more and more recently, for the reason that many patients are unable to

*Corresponding author. Tel: +39 0523 303217, Fax: +39 0523 303220, Email: m.piepoli@ausl.pc.it

achieve maximal aerobic power.[31-33] Repeated tests are also being used for risk stratification and evaluation of interventions, so that more evaluative data are now available. Finally, patients, physicians, and healthcare decision makers are increasingly considering how treatments might impact morbidity and quality of life rather than focusing more exclusively on hard endpoints (such as mortality) as was often the case in the past. Innovative prognostic flowcharts, with CPET at their core, that help optimize risk stratification and the selection of management options in HF patients, have been developed.[34]

Table 1 Comparative features of CPET and 6MWT

	6-min walk test	CPET
Exercise level	Submaximal	Maximal
Reproducibility	+	+++
Availability/cost	+++	+
Patient acceptance	+++	+
Clinical results	+	+++
Prognostic value	++	+++
Patient application	Older/frail	Transplant/VAD list

Six-minute walk test

The role of the walking test for 6 min in providing useful information in patient populations with functional limitations was proposed decades ago.[35] Since that time, the 6-min walk test (6MWT) has gained acceptance in the clinical community as a feasible option to obtain an estimate of cardiovascular functional capacity in disease-based populations known to experience exercise intolerance.[36]

The 6MWT is considered simple in concept in terms of the patient directions. The ATS guidelines provide recommendations for standardizing the communication with the patient during the test.[37] However, it is important to recognize that the 6MWT does not accurately predict peak VO2. Some reports have suggested that failure to achieve a certain distance, such as 300 m or 450 m, on the 6MWT has prognostic value. Additionally, some have proposed that measures other than total distance achieved, such as total work performed or heart rate after 1 min of recovery may provide useful information from the 6MWT. However, there are no well-accepted normative values available to interpret 6MWT results.[38]

The shuttle walk test (SWT) has been also proposed to evaluate chronic disease patient populations.[39] This test requires patients to walk back and forth around two markers on a 10-m course (each 10 m = 1 shuttle) at a pace dictated by audio signals recorded on a cassette tape or CD. The speed is initially set at 0.5 m/s and increased by 0.17 m/s every minute. The test is terminated when the patient cannot complete a shuttle in the required time interval. As with the 6MWT, it is recommended that only standardized comments (no encouragement) be provided and that the SWT is repeated at least twice to account for a learning effect.

Other walking tests have been proposed, i.e. a 100-m walk test in patients with pulmonary disease, 200-m fast walking in patients in cardiac rehabilitation, and a 400-m walk test in patients with HF: however their prognostic powers still need to be documented.[40]

Table 1 summarizes the key differences between CPET vs. 6MWT.

Muscular function

One of the most frequent misconceptions of HF is that the limitations are solely related to the heart.[14,41,42] Evidence has existed for some time that one of significant factors associated with exercise intolerance in patients with HF is skeletal muscle deconditioning.[43,44] Recent studies have identified mechanisms underlying the weakness observed in the skeletal muscles or patients with HF.[45,46]

Thus, is it now well accepted that functional assessments of patients with HF should include measures of muscular performance.[47] The gold standard method to assess muscular strength is the 1−repetition maximum test (1−RM). The resistance for the lifting can be either free weights or resistance exercise machines.

Although a 1−RM can be obtained from any weight lifting exercise, the two most common lifts are the bench press (for upper body strength) and the leg press (for lower body strength). Unfortunately, there are no definitive standards for interpreting 1−RM performance in patients with HF. One of the major issues with performing 1−RM assessments is the time requirement, especially if patients need to be familiarized with using the free weights or machines.

A second option for performing muscular function assessments is to use a handgrip dynamometer. The procedure is simple, only requiring the patient to squeeze the handle of the dynamometer as hard as they can for 3 s. After a short rest, the test is repeated two more times, with each hand being tested. Although normative values specific for patients with HF do not exist, large population standards are available. These tests are starting to be administered in the HF population.[48]

There are also indirect measures of muscular strength that can be used as indicators of muscular functional ability.[49-51] The origins for many of these evaluations came from work with geriatric populations. The method that seems to be gaining the most acceptance is the Short Physical Performance Battery (SPPB).[52]

Questionnaires

Questionnaires have been proposed.[53,54] Myers *et al.* evaluated the Duke Activity Status Index, the Kansas City Cardiomyopathy Questionnaire, and the Veterans Specific Activity Questionnaire, with results from CPET and the 6MWT: these different methods did not correlate well with each other and concluded that they should not be used as surrogate indicators of functional status in this population.[55,56]

Conflict of interest: none declared.

References

1. Montero D, Flammer AJ. Exercise intolerance in heart failure with preserved ejection fraction: time to scrutinize diuretic therapy? *Eur J Heart Fail* 2017;**19**:971–973.
2. Van Iterson EH, Johnson BD, Borlaug BA, Olson TP. Physiological dead space and arterial carbon dioxide contributions to exercise ventilatory inefficiency in patients with reduced or preserved ejection fraction heart failure. *Eur J Heart Fail* 2017;**19**:1675–1685.
3. Baeza-Trinidad R, Mosquera-Lozano JD, El Bikri L. Assessment of bendopnea impact on decompensated heart failure. *Eur J Heart Fail* 2017;**19**:111–115.
4. Lavie CJ, Archer E, Lee DC. Persistent physical activity translating to persistent reduction in mortality. *Eur J Prev Cardiol* 2017;**24**:1612–1614.
5. Chrysohoou C, Skoumas J, Georgiopoulos G, Liontou C, Vogiatzi G, Tsioufis K, Lerakis S, Soulis D, Pitsavos C, Tousoulis D. Exercise capacity and haemodynamic response among 12, 327 individuals with cardio-metabolic risk factors undergoing treadmill exercise. *Eur J Prev Cardiol* 2017;**24**:1627–1636.
6. Fernandes-Silva MM, Guimarães GV, Rigaud VO, Lofrano-Alves MS, Castro RE, de Barros Cruz LG, Bocchi EA, Bacal F. Inflammatory biomarkers and effect of exercise on functional capacity in patients with heart failure: insights from a randomized clinical trial. *Eur J Prev Cardiol* 2017;**24**:808–817.
7. Zhao S, Chen K, Su Y, Hua W, Chen S, Liang Z, Xu W, Dai Y, Liu Z, Fan X, Hou C, Zhang S. Association between patient activity and long-term cardiac death in patients with implantable cardioverter-defibrillators and cardiac resynchronization therapy defibrillators. *Eur J Prev Cardiol* 2017;**24**:760–767.
8. Zafrir B. The prognostic value of exercise testing: exercise capacity, hemodynamic response, and cardio-metabolic risk factors. *Eur J Prev Cardiol* 2017;**24**:1624–1626.
9. Guazzi M. The ultimate diagnosis of unexplained dyspnoea on exertion: stay tuned on invasive cardiopulmonary exercise testing and beyond. *Eur J Prev Cardiol* 2017;**24**:1308–1310.
10. Sabbag A, Mazin I, Rott D, Hay I, Gang N, Tzur B, Goldkorn R, Goldenberg I, Klempfner R, Israel A. The prognostic significance of improvement in exercise capacity in heart failure patients who participate in cardiac rehabilitation programme. *Eur J Prev Cardiol* 2018;**25**:354–361.
11. Lachman S, Boekholdt SM, Luben RN, Sharp SJ, Brage S, Khaw KT, Peters RJ, Wareham NJ. Impact of physical activity on the risk of cardiovascular disease in middle-aged and older adults: EPIC Norfolk prospective population study. *Eur J Prev Cardiol* 2018;**25**:200–208.
12. Antunes-Correa LM. Maximal oxygen uptake: new and more accurate predictive equation. *Eur J Prev Cardiol* 2018;**25**:1075–1076.
13. Guazzi M. Cardiopulmonary exercise testing and risk stratification in heart failure with reduced, midrange or preserved ejection fraction: when nomenclature may not match with pathophysiology. *Eur J Prev Cardiol* 2018;**25**:392–394.
14. Lindgren M, Åberg M, Schaufelberger M, Åberg D, Schiöler L, Torén K, Rosengren A. Cardiorespiratory fitness and muscle strength in late adolescence and long-term risk of early heart failure in Swedish men. *Eur J Prev Cardiol* 2017;**24**:876–884.
15. Palau P, Domínguez E, Núñez J. Clinical utility of cardiopulmonary exercise testing in patients with heart failure with preserved ejection fraction. *Eur J Heart Fail* 2018;**20**:409–410.
16. Sato T, Yoshihisa A, Kanno Y, Suzuki S, Yamaki T, Sugimoto K, Kunii H, Nakazato K, Suzuki H, Saitoh SI, Ishida T, Takeishi Y. Cardiopulmonary exercise testing as prognostic indicators: comparisons among heart failure patients with reduced, mid-range and preserved ejection fraction. *Eur J Prev Cardiol* 2017;**24**:1979–1987.
17. Vanhees L. The prognostic strength of gas analysis measurement during maximal exercise testing. *Eur J Prev Cardiol* 2018;**25**:770–771.
18. Kirkman DL, Muth BJ, Stock JM, Townsend RR, Edwards DG. Cardiopulmonary exercise testing reveals subclinical abnormalities in chronic kidney disease. *Eur J Prev Cardiol* 2018;**25**:1717–1724.
19. Corra' U, Agostoni PG, Anker SD. Role of cardiopulmonary exercise testing in clinical stratification in heart failure. A position paper from the Committee on Exercise Physiology and Training of the Heart Failure Association of the European Society of Cardiology. *Eur J Heart Fail* 2018;**20**:3–15.
20. Laukkanen JA, Araújo CGS, Kurl S, Khan H, Jae SY, Guazzi M, Kunutsor SK. Relative peak exercise oxygen pulse is related to sudden cardiac death, cardiovascular and all-cause mortality in middle-aged men. *Eur J Prev Cardiol* 2018;**25**:772–782.
21. Kleber FX, Köln PJ. Oxygen consumption trajectory flattening-yet another cardiopulmonary exercise testing parameter in chronic heart failure. *Eur J Heart Fail* 2018;**20**:1125–1127.
22. Agostoni P, Guazzi M. Exercise ventilatory inefficiency in heart failure: some fresh news into the roadmap of heart failure with preserved ejection fraction phenotyping. *Eur J Heart Fail* 2017;**19**:1686–1689.
23. Cornelis J, Vrints C, Vissers D, Beckers P. The effect of exercise training on exercise oscillatory ventilation in heart failure. *Eur J Prev Cardiol* 2017;**24**:1283–1284.
24. Panagopoulou N, Karatzanos E, Dimopoulos S, Nanas S. The effect of exercise training on characteristics of exercise oscillatory ventilation in chronic heart failure—reply to the Letter to the Editor. *Eur J Prev Cardiol* 2017;**24**:1285–1286.
25. Panagopoulou N, Karatzanos E, Dimopoulos S, Tasoulis A, Tachliabouris I, Vakrou S, Sideris A, Gratziou C, Nanas S. Exercise training improves characteristics of exercise oscillatory ventilation in chronic heart failure. *Eur J Prev Cardiol* 2017;**24**:825–832.
26. Huang W, Resch S, Oliveira RK, Cockrill BA, Systrom DM, Waxman AB. Invasive cardiopulmonary exercise testing in the evaluation of unexplained dyspnea: insights from a multidisciplinary dyspnea center. *Eur J Prev Cardiol* 2017;**24**:1190–1199.
27. Kokkinos P, Kaminsky LA, Arena R, Zhang J, Myers J. A new generalized cycle ergometry equation for predicting maximal oxygen uptake: the Fitness Registry and the Importance of Exercise National Database (FRIEND). *Eur J Prev Cardiol* 2018;**25**:1077–1082.
28. Crisafulli E, Vigna M, Ielpo A, Tzani P, Mangia A, Teopompi E, Aiello M, Alfieri V, Bertorelli G, Palange P, Chetta A. Heart rate recovery is associated with ventilatory constraints and excess ventilation during exercise in patients with chronic obstructive pulmonary disease. *Eur J Prev Cardiol* 2018;**25**:1667–1674.
29. Mantegazza V, Contini M, Botti M, Ferri A, Dotti F, Berardi P, Agostoni P. Improvement in exercise capacity and delayed anaerobic metabolism induced by far-infrared-emitting garments in active healthy subjects: a pilot study. *Eur J Prev Cardiol* 2018;**25**:1744–1751.
30. Saeidifard F, Medina-Inojosa JR, Supervia M, Olson TP, Somers VK, Erwin PJ, Lopez-Jimenez F. Differences of energy expenditure while sitting versus standing: a systematic review and meta-analysis. *Eur J Prev Cardiol* 2018;**25**:522–538.
31. Guazzi M. Adjusting exercise ventilation efficiency for age: a step forward for optimizing prediction of outcome especially in heart failure with preserved ejection fraction. *Eur J Prev Cardiol* 2018;**25**:728–730.
32. Kato Y, Suzuki S, Uejima T, Semba H, Nagayama O, Hayama E, Arita T, Yagi N, Kano H, Matsuno S, Otsuka T, Oikawa Y, Kunihara T, Yajima J, Yamashita T. Relationship between the prognostic value of ventilatory efficiency and age in patients with heart failure. *Eur J Prev Cardiol* 2018;**25**:731–739.
33. Crisafulli E, Scelfo C, Tzani P, Aiello M, Bertorelli G, Chetta A. Asymptomatic peripheral artery disease can limit maximal exercise capacity in chronic obstructive pulmonary disease patients regardless of airflow obstruction and lung hyperinflation. *Eur J Prev Cardiol* 2017;**24**:990–999.
34. Fernberg U, Fernström M, Hurtig-Wennlöf A. Arterial stiffness is associated to cardiorespiratory fitness and body mass index in young Swedish adults: the Lifestyle, Biomarkers, and Atherosclerosis study. *Eur J Prev Cardiol* 2017;**24**:1809–1818.
35. Griffo R, Spanevello A, Temporelli PL, Faggiano P, Carone M, Magni G, Ambrosino N, Tavazzi L; SUSPIRIUM Investigators. Frequent coexistence of chronic heart failure and chronic obstructive pulmonary disease in respiratory and cardiac outpatients: evidence from SUSPIRIUM, a multicentre Italian survey. *Eur J Prev Cardiol* 2017;**24**:567–576.
36. Kamiya K, Hamazaki N, Matsue Y, Mezzani A, Corrà U, Matsuzawa R, Nozaki K, Tanaka S, Maekawa E, Noda C, Yamaoka-Tojo M, Matsunaga A, Masuda T, Ako J. Gait speed has comparable prognostic capability to six-minute walk distance in older patients with cardiovascular disease. *Eur J Prev Cardiol* 2018;**25**:212–219.
37. Wolsk E, Kaye D, Borlaug BA, Burkhoff D, Kitzman DW, Komtebedde J, Lam CSP, Ponikowski P, Shah SJ, Gustafsson F. Resting and exercise

haemodynamics in relation to six-minute walk test in patients with heart failure and preserved ejection fraction. *Eur J Heart Fail* 2018; **20**:715–722.
38. Mandini S, Grazzi G, Mazzoni G, Myers J, Pasanisi G, Sassone B, Conconi F, Chiaranda G. A moderate 1-km treadmill walk predicts mortality in men with mid-range left ventricular dysfunction. *Eur J Prev Cardiol* 2017;**24**:1670–1672.
39. Haapala EA, Lankhorst K, de Groot J, Zwinkels M, Verschuren O, Wittink H, Backx FJ, Visser-Meily A, Takken T; HAYS study group. The associations of cardiorespiratory fitness, adiposity and sports participation with arterial stiffness in youth with chronic diseases or physical disabilities. *Eur J Prev Cardiol* 2017;**24**:1102–1111.
40. Cugusi L, Manca A, Yeo TJ, Bassareo PP, Mercuro G, Kaski JC. Nordic walking for individuals with cardiovascular disease: a systematic review and meta-analysis of randomized controlled trials. *Eur J Prev Cardiol* 2017;**24**:1938–1955.
41. Giannoni A, Aimo A, Mancuso M, Piepoli MF, Orsucci D, Aquaro GD, Barison A, De Marchi D, Taddei C, Cameli M, Raglianti V, Siciliano G, Passino C, Emdin M. Autonomic, functional, skeletal muscle, and cardiac abnormalities are associated with increased ergoreflex sensitivity in mitochondrial disease. *Eur J Heart Fail* 2017;**19**:1701–1709.
42. Graziani F, Varone F, Crea F, Richeldi L. Treating heart failure with preserved ejection fraction: learning from pulmonary fibrosis. *Eur J Heart Fail* 2018;**20**:1385–1391.
43. Ventura HO, Carbone S, Lavie CJ. Muscling up to improve heart failure prognosis. *Eur J Heart Fail* 2018;**20**:1588–1590.
44. Iliou MC, Vergès-Patois B, Pavy B, Charles-Nelson A, Monpère C, Richard R, Verdier JC; on behalf for the CREMS-HF (Cardiac REhabilitation and electrical MyoStimulation-Heart Failure) study group. Effects of combined exercise training and electromyostimulation treatments in chronic heart failure: a prospective multicentre study. *Eur J Prev Cardiol* 2017;**24**:1274–1282.
45. Montero D, Lundby C. Reduced arteriovenous oxygen difference in heart failure with preserved ejection fraction patients: is the muscle oxidative phenotype certainly involved? *Eur J Prev Cardiol* 2017;**24**:1157–1160.
46. Meijers WC, de Boer RA. Exercise and heart failure: improve your functional status and your biomarker profile. *Eur J Prev Cardiol* 2017;**24**:1358–1359.
47. Kadoglou NP, Mandila C, Karavidas A, Farmakis D, Matzaraki V, Varounis C, Arapi S, Perpinia A, Parissis J. Effect of functional electrical stimulation on cardiovascular outcomes in patients with chronic heart failure. *Eur J Prev Cardiol* 2017;**24**:833–839.
48. Emami A, Saitoh M, Valentova M, Sandek A, Evertz R, Ebner N, Loncar G, Springer J, Doehner W, Lainscak M, Hasenfuß G, Anker SD, von Haehling S. Comparison of sarcopenia and cachexia in men with chronic heart failure: results from the Studies Investigating Comorbidities Aggravating Heart Failure (SICA-HF). *Eur J Heart Fail* 2018;**20**:1580–1587.
49. Compostella L, Compostella C, Truong LV, Russo N, Setzu T, Iliceto S, Bellotto F. History of erectile dysfunction as a predictor of poor physical performance after an acute myocardial infarction. *Eur J Prev Cardiol* 2017;**24**:460–467.
50. Bona RL, Bonezi A, Silva PF, Biancardi CM, Castro FA, Clausel NO. Electromyography and economy of walking in chronic heart failure and heart transplant patients. *Eur J Prev Cardiol* 2017;**24**:544–551.
51. Mandigout S, Lacroix J, Ferry B, Vuillerme N, Compagnat M, Daviet JC. Can energy expenditure be accurately assessed using accelerometry-based wearable motion detectors for physical activity monitoring in post-stroke patients in the subacute phase? *Eur J Prev Cardiol* 2017;**24**:2009–2016.
52. Marcos-Forniol E, Meco JF, Corbella E, Formiga F, Pintó X. Secondary prevention programme of ischaemic heart disease in the elderly: a randomised clinical trial. *Eur J Prev Cardiol* 2018;**25**:278–286.
53. Aaby A, Friis K, Christensen B, Rowlands G, Maindal HT. Health literacy is associated with health behaviour and self-reported health: a large population-based study in individuals with cardiovascular disease. *Eur J Prev Cardiol* 2017;**24**:1880–1888.
54. Schnohr P, O'Keefe JH, Lange P, Jensen GB, Marott JL. Impact of persistence and non-persistence in leisure time physical activity on coronary heart disease and all-cause mortality: the Copenhagen City Heart Study. *Eur J Prev Cardiol* 2017;**24**:1615–1623.
55. Ware LJ, Rennie KL, Schutte AE. Monitoring physical activity after a cardiovascular event: what is 'fit' for purpose? *Eur J Prev Cardiol* 2018;**25**:220–222.
56. Vasankari V, Husu P, Vähä-Ypyä H, Suni J, Tokola K, Halonen J, Hartikainen J, Sievänen H, Vasankari T. Association of objectively measured sedentary behaviour and physical activity with cardiovascular disease risk. *Eur J Prev Cardiol* 2017;**24**:1311–1318.