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REVIEW

A systematic review of rehabilitation in chronic heart failure: evaluating the reporting of exercise interventions

Amy E. Harwood[1]*, Sophie Russell[1], Nduka C. Okwose[1,2], Scott McGuire[1], Djordje G. Jakovljevic[1,2,3] and Gordon McGregor[1,4]

[1]*Centre for Sport, Exercise and Life Sciences, Faculty of Health and Life Sciences, Science and Health Building, Whitefriars Street, Coventry University, Coventry, CV1 2DS, UK;* [2]*Cardiovascular Research Division, Translational and Clinical Research Institute, Newcastle University, UK;* [3]*Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, UK; and* [4]*Department of Cardiopulmonary Rehabilitation, Centre for Exercise and Health, University Hospitals Coventry & Warwickshire NHS Trust, Coventry, UK*

Abstract

A large body of research supports the use of exercise to improve symptoms, quality of life, and physical function in patients with chronic heart failure. Previous reviews have focused on reporting outcomes of exercise interventions such as cardiorespiratory fitness. However, none have critically examined exercise prescription. The aim of this review was to evaluate the reporting and application of exercise principles in randomised control trials of exercise training in patients with chronic heart failure. A systematic review of exercise intervention RCTs in patients with CHF, using the Consensus on Exercise Reporting Template (CERT), was undertaken. The Ovid Medline/PubMed, Embase, Scopus/Web of Science, and Cochrane Library and Health Technology Assessment Databases were searched from 2000 to June 2020. Prospective RCTs in which patients with CHF were randomized to a structured exercise programme were included. No limits were placed on the type or duration of exercise structured exercise programme or type of CHF (i.e. preserved or reduced ejection fraction). We included 143 studies, comprising of 181 different exercise interventions. The mean CERT score was 10 out of 19, with no study achieving a score of 19. Primarily, details were missing regarding motivational strategies, home-based exercise components, and adherence/fidelity to the intervention. Exercise intensity was the most common principle of exercise prescription missing from intervention reporting. There was no improvement in the reporting of exercise interventions with time (R^2 = 0.003). Most RCTs of exercise training in CHF are reported with insufficient detail to allow for replication, limiting the translation of evidence to clinical practice. We encourage authors to provide adequate details when reporting future interventions. Where journal word counts are restrictive, we recommend using supplementary material or publishing trial protocols prior to beginning the study.

Keywords Heart failure; Systematic review; Exercise training

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**Correspondence to: Amy E. Harwood, Centre for Sport, Exercise and Life Sciences, Faculty of Health and Life Sciences, Science and Health Building, Whitefriars Street, Coventry University, Coventry CV1 2DS, UK. Tel: +44 7546 370 405. Email: amy.harwood@coventry.ac.uk*
Institution where the work was performed: Coventry University.

Introduction

Chronic heart failure (CHF) is characterized by the reduced ability of the heart to pump and or fill with blood, resulting in fatigue, dyspnoea, and exercise intolerance.[1] It is a significant healthcare challenge affecting around 26 million people worldwide,[2] with a prevalence of 1–3% of the general population increasing to around 10% in those aged 70 and over.[3] Patients with CHF often have reduced functional capacity and decreased quality of life.[4]

A range of pharmacological (angiotensin II receptor blockers, diuretics, beta-blockers, cardiac glycosides, and anticoagulants), medical (cardiac resynchronization therapy), and lifestyle (smoking cessation and reduced salt intake) interventions can help improve quality of life and reduce hospital admissions in CHF.[5] In addition, structured exercise training is recommended and should be an integral part of the treatment pathway.

There is evidence for the benefits of exercise training in New York Heart Association class I-III CHF patients, with

numerous randomized controlled trials reporting improvements in health-related quality of life, cardiorespiratory function, and physical activity participation.[6–8] These benefits have been identified using a range of exercise training intervention modalities such as high intensity interval training,[9] moderate intensity training,[10] and resistance training.[11]

Despite evidence of the therapeutic role of exercise training in CHF populations, the heterogeneity of interventions limits understanding of the most effective prescription. A range of exercise frequencies, intensities, modalities, and durations have been reported in the management of CHF. The plethora of exercise intervention models available for the treatment of CHF requires that frequency, intensity, time, and type of exercise be accurately reported, as proposed in the consensus on exercise reporting template (CERT).[12] These criteria, which are often inadequately reported in exercise clinical trials, are fundamental for translation, interpretation, and implementation within clinical practice.[13]

To date, no review has fully evaluated the reporting of exercise interventions in CHF, risking sub-therapeutic exercise prescription despite proposed efficacy of treatment. This review, therefore evaluated using the CERT criteria, randomized controlled trials of exercise interventions in patients with CHF in relation to (i) the principles of exercise prescription (i.e. frequency, intensity, time, and type) and (ii) the reporting of intervention components related to exercise prescription.

Methods

This review was conducted in line with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidance.[14] As we did not report any specific health care outcomes, we could not prospectively register this review on PROSPERO.

Search strategy

The Ovid Medline/PubMed, Embase, Scopus/Web of Science, Cochrane Library, and Health Technology Assessment Databases were searched from 2000 to June 2020. Only full text articles involving adults over 18 years of age and published in the English language were considered. Search terms included ‘heart failure’, ‘exercise training’, and ‘rehabilitation’. Titles and abstracts identified were independently interrogated for inclusion by two reviewers (A. E. H. and S. R.). The full texts of any potentially eligible articles were then screened against the inclusion/exclusion criteria.

Inclusion criteria

We included prospective randomized controlled trials in which patients with CHF were randomized to a structured exercise programme. No limits were placed on the type or duration of exercise structured exercise programme. We also placed no limits on type of CHF (i.e. preserved or reduced ejection fraction).

Exclusion criteria

Alternative interventions such as yoga, Pilates, or Tai Chi, as well as specific therapeutic interventions (such as drug therapies) were excluded. In addition, randomized controlled trials in which the intervention was exclusively behavioural were excluded. We also excluded duplicate papers whereby the pilot and subsequent randomized trial reported the same exercise intervention. Studies published before 2000 were excluded due to them predating the publication of the European Society of Cardiology clinical exercise guidelines which outlined specific exercise prescription recommendations.[15]

Data extraction

Data extraction was performed by two reviewers (A. E. H. and S. R.) using a standardized form. Data pertaining to search results, duplicates, and included and excluded (with explanation) studies were recorded.

Data extraction included study characteristics (country, design, and appropriate information to assess the quality of the study), sample size, and a detailed description of the intervention according to the ‘FITT principle’; defined as the Frequency, Intensity, Time, and Type. Studies were rated for each of the principles of exercise training based on the reported application of the principle within the paper. Application of a specific principle was assigned a ‘1’, whereas ‘0’ was assigned if the principle was not reported. Where data were unclear, or if the principle was reported but used inconsistently, we also assigned a ‘0’. In addition, we used the ‘Consensus on Exercise Reporting Template’[12] to provide each paper with an objective score out of 19.

Consensus on exercise reporting

The ‘Consensus on Exercise Reporting’ (CERT) template is a 16-item checklist designed to evaluate the completeness of exercise intervention reporting and spans the ‘who’, ‘what’, ‘when’, ‘where’, and ‘how’. We utilized the CERT ‘Explanation and Elaboration Statement’ to ensure methodological quality of scoring.[12] Each item of the CERT was scored ‘1’ (adequately reported) or ‘0’ (not adequately reported,

unclear, or not reported at all). A maximum score of 19 can be achieved. Where studies cited methodology from previous work or referenced protocols or supplementary materials, we also checked information from these sources and included them in the scoring as appropriate. Due to the volume of studies included, four authors (A. E. H., S. R., N. C. O., and S. M.) scored studies, with A. E. H. and S. R. verifying all scores independently in cases of uncertainty.

Data synthesis

Data were synthesized, and studies rated based on the application of exercise training principles and the CERT template. The percentage of studies meeting each criterion; application of the principles of exercise training; reporting of the components of prescription using the aforementioned FITT principles; and the CERT were calculated. To determine whether improvements/differences occurred over time, an R^2 test was utilized.

Results

Included studies

The search yielded a total of 53 429 records, of which, 575 full-text articles were assessed for eligibility. Of these, we included 143 studies, comprising 181 different exercise interventions (*Figure 1*).[16–158] In total, there were 11 752 participants of which 6429 were randomized to an exercise intervention with 5787 (90%) completed the intervention.

The exercise interventions included 14 home-based interventions and 167 centre-based interventions. Exercise modalities included aerobic exercise training (116/181), resistance training (17/181), high-intensity interval training (11/181), and 37/181 studies where a mixed intervention was applied. The length of intervention ranged from 3 weeks[36] to 14 months.[121]

Application of the principles of exercise training

The application of the principles of exercise training is outlined in *Figure 2*. The FITT principle in CHF interventions was very well reported. However, at least one component was not reported in 24 (17%) of the 143 interventions,[23–25,28,30,34,49,55,61,66,72,75,79,83,89,90,92,100,111,114,118,151,152,155] and in two studies, none of the principles of exercise training was reported.[25,75] The most poorly (or 'worst') reported principle of exercise training was intensity which was not reported in 12 out of 181 interventions.[23,25,28,49,66,72,75,114,118,151,152,155] All studies where intensity was not reported were centre-based programmes and across all exercise modalities —aerobic,[23,28,49,66,72,151,155] resistance,[75,114,152] or mixed interventions.[25,118]

Reporting of exercise intervention components

The reporting of the exercise intervention components is summarized in *Figure 3*. None of the studies scored by CERT achieved 100%. Further, the mean CERT score in all 181 interventions was 10 out of a possible score of 19. The lowest CERT score was 2/19 with all information missing with the exception of 'setting' and 'whether the intervention was delivered as planned'. The highest CERT score was 18/19, which was obtained by two studies with two details not reported: 'description of home components' and 'description or expertise of instructors', respectively. The least reported components included 'detailed description of motivation strategies', 'detailed description of any home programme component', and 'description of how adherence or fidelity to the exercise intervention is assessed/measured'. The best reported outcomes included 'description of whether exercise is supervised or unsupervised and how they are delivered' and whether exercises were 'generic (one size fits all) or tailored to the individual'.

○ Question 1: Detailed description of the type of exercise equipment

Most studies described the mode (i.e. treadmill walking or cycling) but did not provide an adequate description of the make and/or model of the exercise equipment. Particularly regarding resistance exercise, very few descriptions beyond 'resistance machines' or 'dumbbells' were provided.

○ Question 2: Detailed description of the qualifications, expertise, and/or training

Only 31% of interventions provided information on the specific professional disciplines delivering the intervention. Those disciplines included physiotherapists, nurses, and exercise physiologists. Generally, there were no details about qualifications, but phrases such as 'highly trained' or 'experienced' were used.

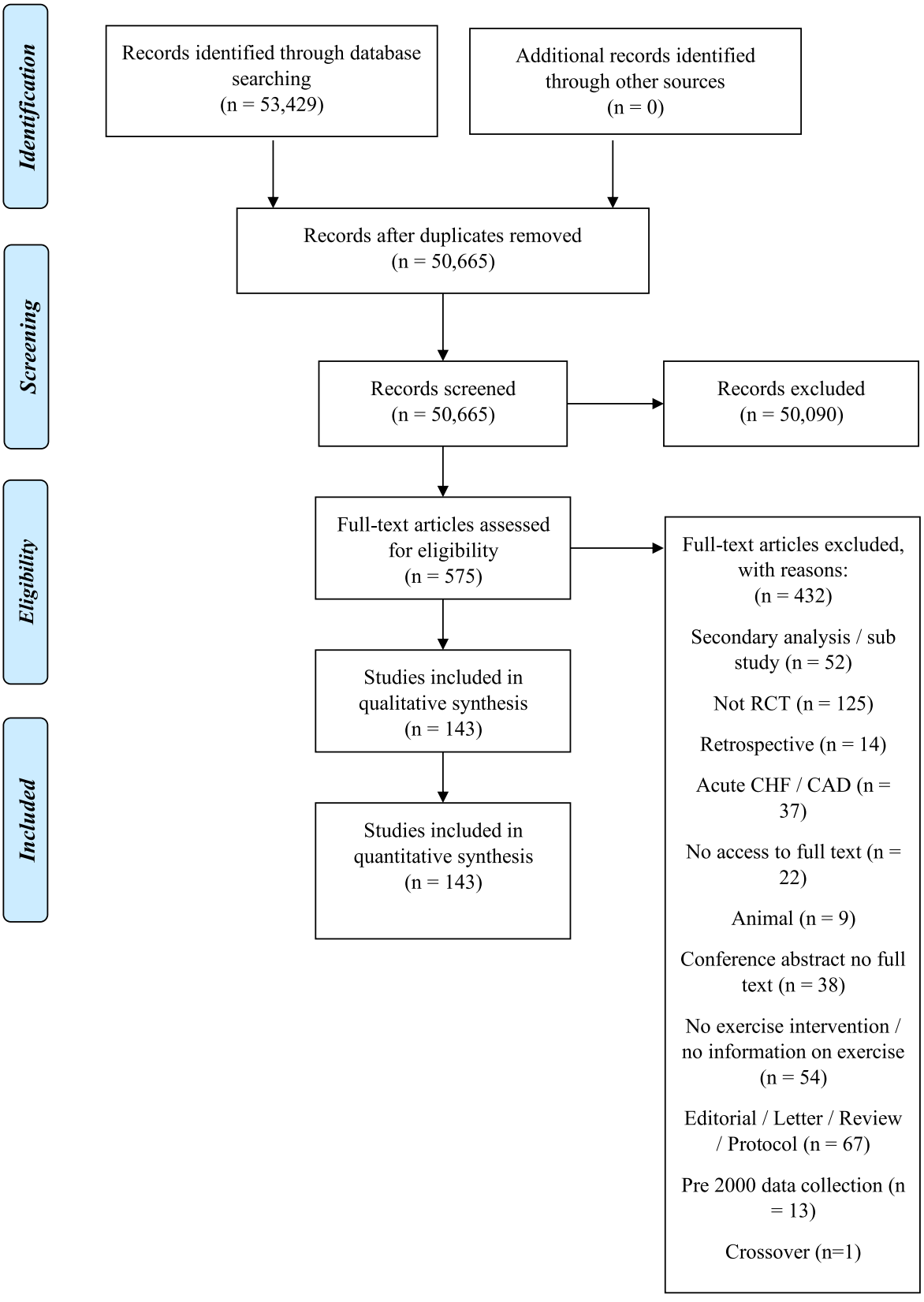
○ Question 3: Describe whether exercise is performed individually or in a group

Only 31% of interventions described whether exercises were group-based or performed individually.

○ Question 4: Describe whether exercise is supervised or unsupervised; how they are delivered

Most interventions (77%) provided a description of whether exercises were delivered in a supervised or unsupervised

FIGURE 1 PRISMA flow diagram.



format. For those interventions that were unsupervised, all were home-based exercise programmes.

○ Question 5: Detailed descriptions of how adherence to exercise is measured and reported

The methodology for reported adherence to exercise was poor, with only 37% of interventions reporting this adequately. Where it was measured, it was usually recorded as attendance to training via diaries, telephone calls, and physical monitoring of attendance.

○ Question 6: Detailed description of motivational strategies

Only 14% (26/181) of interventions provided details regarding motivational strategies. Where strategies were employed, motivational interviewing, educational support, and regular support were the most common.

○ Question 7a: Detailed description of the decision rule(s) for determining exercise progression; 7b: Detailed description of how the exercise programme was progressed

The decision rule(s) for progression were only identified in 28% (52/181) of included interventions. Mostly the decision to progress was based on rating of perceived exertion or heart rate responses. Despite only 28% of interventions provided decisions rules for progression, 47% did provide descriptions of how programmes were actually progressed. Progression was administered in a number of ways including increasing the intensity and duration of exercise.

○ Question 8: Detailed description of each exercise to enable replication

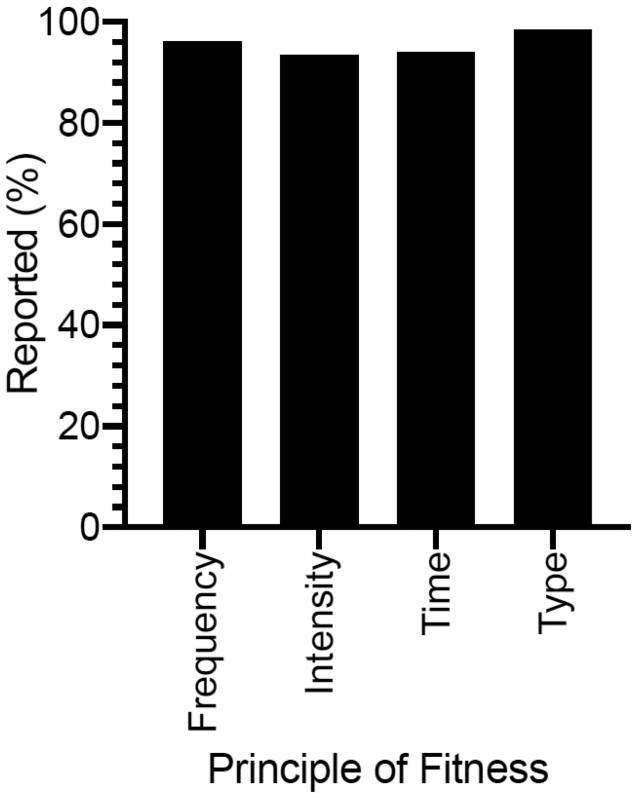
Detailed descriptions of exercise were evident in 58% (110/181) of interventions. Predominantly, information was missing in instances where aerobic circuit-based training sessions were utilized, but individual exercises were not reported.

○ Question 9: Detailed description of any home programme component

Detailed description of home programme components was only provided in 21% (40/181) of interventions. Where programmes were entirely home-based, these were scored as '1'.[42,46,49,58,64,73,75,82,93,94,101,107,115,117] Where details were provided, these were non-specific such as 'patients were advised they could do more exercise at home if they wished'.

○ Question 10: Description of whether there are any non-exercise components

FIGURE 2 Reporting of the principles of exercise training.



Description/information regarding non-exercise components was identified in 21% (40/181) of interventions. The most common non-exercise component was education session(s).

○ Question 11: Describe the type and number of adverse events that occurred during exercise

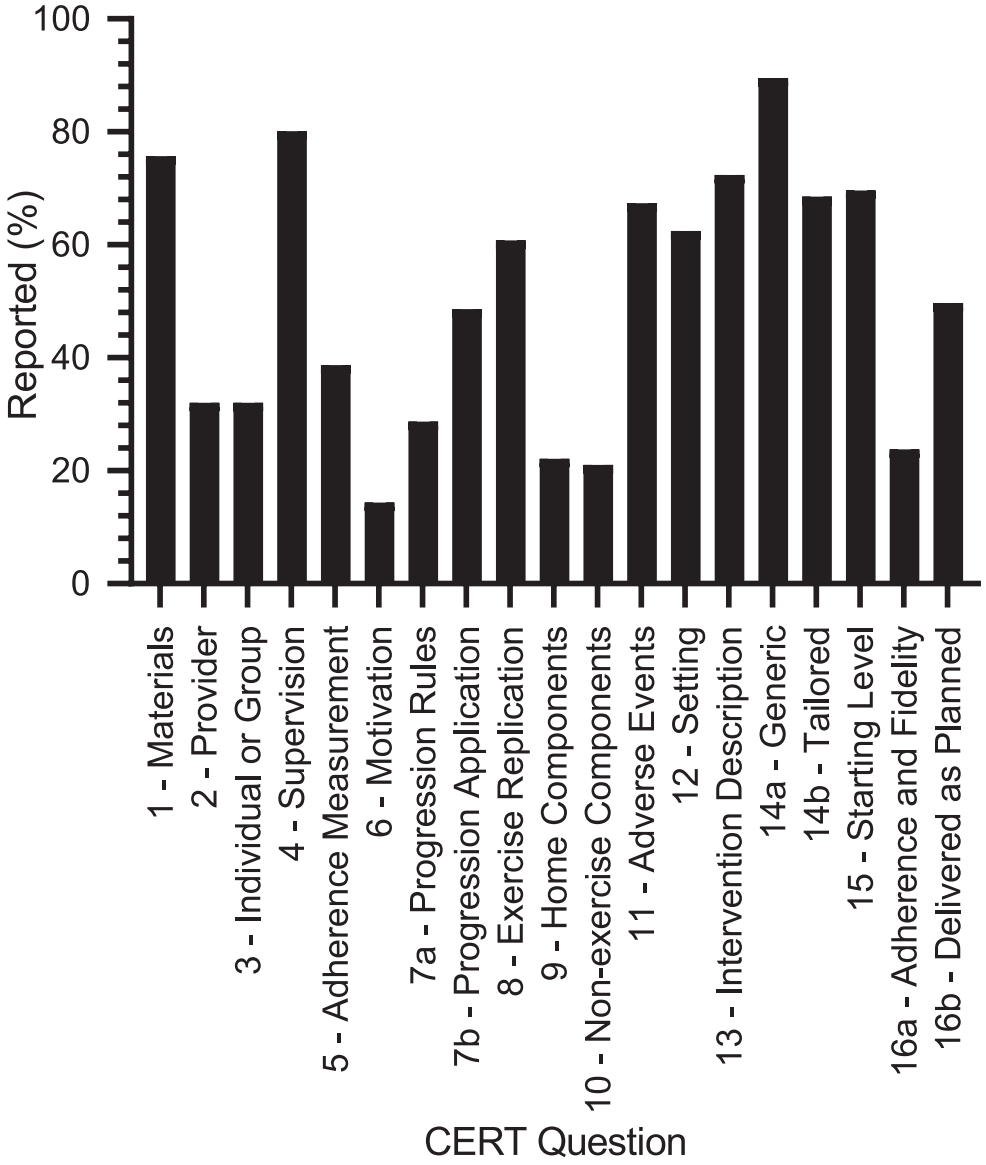
Overall, 65% of interventions reported whether or not there were any adverse events. Some studies provided information regarding severity, while others reported 'no adverse events occurred'.

○ Question 12: Describe the setting in which the exercises are performed

In total, 60% (122/181) of interventions clearly described where the exercise programme took place. The remaining 40% did not provide any details to clearly define the setting.

○ Question 13: Detailed description of the exercise intervention; Question 14a: Describe whether the exercises are generic (one-size-fits-all) or tailored; 14b: Detailed description of how exercises are tailored to the individual

FIGURE 3 Consensus on exercise reporting outcome for all interventions (n = 181).



There was variability in the level of detail, but 65% of interventions provided an adequate description of the exercise intervention in line with CERT recommendations. Detailed descriptions of tailoring of programmes was one of the best reported CERT components, identified in 86% of interventions (131/181).

○ Question 15: Describe the decision rule for determining the starting level

A decision for determining the starting level of exercise was identified in 66% of interventions. A large proportion of interventions were based on variables determined from cardiopulmonary exercise testing.

○ Question 16a: Describe how adherence or fidelity is assessed/measured; 16b: Describe the extent to which the intervention was delivered as planned

A description of how adherence or fidelity was assessed or measured was only reported in 23% (43/181) of interventions. Generally, this was measured via heart rate or rating of perceived exertion during sessions. Despite most studies not identifying how adherence was measured, 49% of

assessed interventions provided a description of whether the intervention was delivered as planned.

Improvement over time

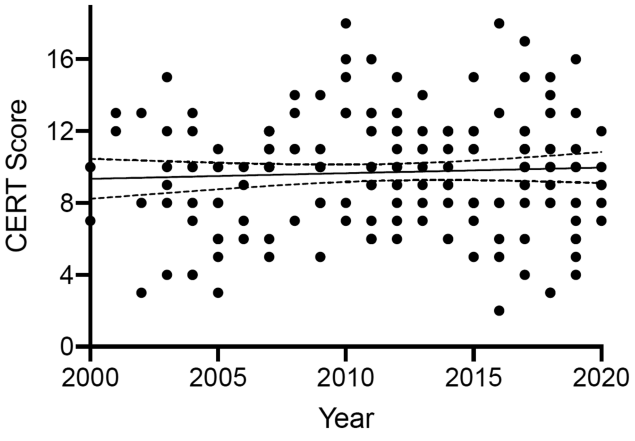
We assessed if reporting of exercise interventions improved over time from 2000 to 2020. There was no significant relationship (R^2 = 0.003) between year of study and quality of study reporting (*Figure 4*).

Discussion

There are a multitude of studies examining the benefits of exercise training for patients with CHF. These studies have provided a vast amount of evidence relating to the safety, feasibility, and health benefits of exercise in this population.[7] However, there has been no evaluation of the application of the basic principles of exercise training or the quality of study reporting. We used the CERT criteria to evaluate 143 randomized controlled trials of exercise interventions in patients with CHF. Our review had two main aims: (i) to assess the application of the principles of exercise prescription (i.e. frequency, intensity, time, and type) and (ii) to assess the reporting of exercise intervention components.

Our main finding was that the overall reporting of exercise interventions (as assessed by the CERT) was poor. The mean CERT score was 10 out of 19, with 80/181 (45%) of interventions scoring less than the mean. The worst reported components included 'detailed description of motivation strategies', 'detailed description of any home programme component', and 'description of how adherence or fidelity to the exercise intervention is assessed/measured'. Poor reporting of exercise interventions may impact on the ability to translate research findings into meaningful clinical interventions and may ultimately impact any potential benefits for patients.

FIGURE 4 Overview of change with time for studies (*n* = 143).



Motivational strategies were poorly reported overall and could only be identified in 14% of all interventions (26/181). Good adherence to exercise and general physical activity, health and wellbeing behaviours may be achieved via effective behaviour change.[93,159,160] The most common form of motivational strategy in the included studies was an education group or the use of standard verbal encouragement during exercise sessions. Other forms of behaviour change strategies that were used include patient diaries and goal setting.[161] It is likely that improving this component of exercise interventions will improve adherence and may lead to better patient outcomes. Indeed, the 'Rehabilitation Enablement in Chronic Heart Failure' (REACH-HF) trial demonstrated that those who received a behaviour change intervention had superior quality of life outcomes following 12 weeks of cardiac rehabilitation and that the intervention was feasible and well accepted by both patients and caregivers.[162] A similar remotely delivered physical activity behaviour change intervention demonstrated that 'lifestyle coaching' enabled patients to reduce fear of physical activity and improved motivation and confidence.[163] It is evident that behaviour change constitutes a vital component of exercise interventions, and therefore, good quality reporting is essential to allow for replication and translation from research to clinical practice.

The methodology for recording and reporting 'adherence or fidelity to the exercise intervention' was also poorly reported, and we only identified 23% (43/181) of interventions where this was appropriately measured. When measured, it was predominantly related to the percentage of exercise sessions attended. In a small minority of studies, fidelity was monitored through the measurement of heart rate during the sessions (related to intensity), but data were not provided by the authors. Intervention fidelity is important in determining the validity of randomized controlled trials.[164,165] There are several different components to intervention fidelity. In exercise trials, information about compliance with exercise prescription is particularly important and is integral to quantifying the intended dose of exercise and the dose that participants actually received.[166]

Most studies adequately described the principles of exercise training (including frequency, intensity, time, and type). Previous analysis of the principles of exercise training inn other clinical cohorts have demonstrated heterogeneity in results. For instance, a review of exercise in breast cancer patients demonstrated poor reporting,[167] while another review in pulmonary hypertension demonstrated excellent reporting.[168] The principle of exercise training that was least reported in both reviews was intensity. This is of great concern given that intensity is an integral component of any exercise intervention, particularly in relation to specificity and progression. Even where exercise intensity was reported, parameters were highly variable including rating of perceived exertion, anaerobic threshold, % of peak oxygen

consumption (VO_2), % of peak heart rate, % of heart rate reserve, and so forth. This variation in markers of exercise intensity is likely to cause challenges in identifying the most appropriate methods in this cohort. Indeed, while not necessarily related to poor reporting, evidence has emerged demonstrating that a large proportion of patients undertaking cardiac rehabilitation do not exercise at a sufficient intensity to improve cardiorespiratory fitness.[169] Understanding and ensuring that intensity is well-defined, monitored during exercise, and clearly reported are essential.

Finally, we wanted to address whether the reporting of exercise interventions has improved over time (*Figure 3*). Our analysis indicated that the quality of reporting has not improved with time which corresponds to previous research in patients undergoing cardiac rehabilitation.[170] It may be that tight restrictions on word count within journals limits authors' ability to provide adequate descriptions of exercise interventions. However, authors should be able to provide further information in the form of supplementary material or published protocols.

Conclusion

There is a wealth of evidence to support the use of exercise training for patients with chronic heart failure. Our study found that most randomized controlled trials of exercise training in this population did not report their interventions with enough detail. The major areas of weakness included intervention adherence and fidelity, exercise intensity, motivational strategies, and home-based components of the intervention. These inadequacies in reporting may limit application to clinical practice and future research. We would encourage all authors to provide adequate details when reporting interventions in the future, in line with the CERT criteria. Where journal publication criteria are restrictive, we recommend using supplementary material or publishing protocols prior to the beginning of the study.

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Conflict of interest

None declared.

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Author conributions

A.H. and G.M. provided idea conception. All authors contributed to the design of the study. S.R. and A.H. were responsible for searching and identifying appropriate studies. All authors were responsible for scoring studies/data analysis, and A.H. and S.R. verified accuracy. All authors were responsible for writing, proof-reading, and approving the manuscript for submission.

Data availability statement

Data will be made available upon request.

References

1. Coronel R, de Groot JR, van Lieshout JJ. Defining heart failure. *Cardiovasc Res* 2001; **50**: 419–422.
2. Ponikowski P, Anker SD, AlHabib KF, Cowie MR, Force TL, Hu S, Jaarsma T, Krum H, Rastogi V, Rohde LE, Samal UC, Shimokawa H, Budi Siswanto B, Sliwa K, Filippatos G. Heart failure: preventing disease and death worldwide. *ESC Heart Fail* 2014; **1**: 4–25.
3. Savarese G, Lund LH. Global public health burden of heart failure. *Card Fail Rev* 2017; **3**: 7–11.
4. Lewis EF, Lamas GA, O'Meara E, Granger CB, Dunlap ME, McKelvie RS, Probstfield JL, Young JB, Michelson EL, Halling K, Carlsson J, Olofsson B, McMurray JJ, Yusuf S, Swedberg K, Pfeffer MA, Investigators C. Characterization of health-related quality of life in heart failure patients with preserved versus low ejection fraction in CHARM. *Eur J Heart Fail* 2007; **9**: 83–91.
5. Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JGF, Coats AJS, Falk V, Gonzalez-Juanatey JR, Harjola VP, Jankowska EA, Jessup M, Linde C, Nihoyannopoulos P, Parissis JT, Pieske B, Riley JP, Rosano GMC, Ruilope LM, Ruschitzka F, Rutten FH, van der Meer P, Group ESCSD. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur Heart J* 2016; **37**: 2129–2200.
6. Smart N, Marwick TH. Exercise training for patients with heart failure: a systematic review of factors that improve mortality and morbidity. *Am J Med* 2004; **116**: 693–706.
7. Morris JH, Chen L. Exercise training and heart failure: a review of the literature. *Card Fail Rev* 2019; **5**: 57–61.
8. Taylor RS, Long L, Mordi IR, Madsen MT, Davies EJ, Dalal H, Rees K, Singh SJ, Gluud C, Zwisler AD. Exercise-based rehabilitation for heart failure: cochrane systematic review, meta-

analysis, and trial sequential analysis. *JACC Heart Fail* 2019; **7**: 691–705.
9. Wewege MA, Ahn D, Yu J, Liou K, Keech A. High-intensity interval training for patients with cardiovascular disease-is it safe? A systematic review. *J Am Heart Assoc* 2018; **7**: e009305.
10. Pina IL, Apstein CS, Balady GJ, Belardinelli R, Chaitman BR, Duscha BD, Fletcher BJ, Fleg JL, Myers JN, Sullivan MJ, American Heart Association Committee on exercise r, prevention. Exercise and heart failure: a statement from the American Heart Association Committee on exercise, rehabilitation, and prevention. *Circulation* 2003; **107**: 1210–1225.
11. Jewiss D, Ostman C, Smart NA. The effect of resistance training on clinical outcomes in heart failure: a systematic review and meta-analysis. *Int J Cardiol* 2016; **221**: 674–681.
12. Slade SC, Dionne CE, Underwood M, Buchbinder R. Consensus on Exercise Reporting Template (CERT): explanation and elaboration statement. *Br J Sports Med* 2016; **50**: 1428–1437.
13. Slade SC, Keating JL. Exercise prescription: a case for standardised reporting. *BJSM* 2012; **46**: 1110–1113.
14. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009; **339**: b2535.
15. Remme WJ, Swedberg K, Task Force for the D, Treatment of Chronic Heart Failure ESoC. Guidelines for the diagnosis and treatment of chronic heart failure. *Eur Heart J* 2001; **22**: 1527–1560.
16. Abdelbasset WK, Alqahtani BA, Elshehawy AA, Tantawy SA, Elnegamy TE, Kamel DM. Examining the impacts of 12 weeks of low to moderate-intensity aerobic exercise on depression status in patients with systolic congestive heart failure—a randomized controlled study. *Clinics (Sao Paulo)* 2019; **74**: e1017-e.
17. Abolahrari-Shirazi S, Kojuri J, Bagheri Z, Rojhani-Shirazi Z. Efficacy of combined endurance-resistance training versus endurance training in patients with heart failure after percutaneous coronary intervention: a randomized controlled trial. *J Res Med Sci* 2018; **23**: 12.
18. Adamopoulos S, Schmid JP, Dendale P, Poerschke D, Hansen D, Dritsas A, Kouloubinis A, Alders T, Gkouziouta A, Reyckers I, Vartela V, Plessas N, Doulaptsis C, Saner H, Laoutaris ID. Combined aerobic/inspiratory muscle training vs. aerobic training in patients with chronic heart failure: The Vent-HeFT trial: a European prospective multicentre randomized trial. *Eur J Heart Fail* 2014; **16**: 574–582.
19. Ajiboye OA, Anigbogu CN, Ajuluchukwu JN, Jaja SI. Exercise training improves functional walking capacity and activity level of Nigerians with chronic biventricular heart failure. *Hong Kong Physiother J* 2015; **33**: 42–49.
20. Aksoy S, Findikoglu G, Ardic F, Rota S, Dursunoglu D. Effect of 10-week supervised moderate-intensity intermittent vs. continuous aerobic exercise programs on vascular adhesion molecules in patients with heart failure. *Am J Phys Med Rehabil* 2015; **94**: 898–911.
21. Alves AJ, Ribeiro F, Goldhammer E, Rivlin Y, Rosenschein U, Viana JL, Duarte JA, Sagiv M, Oliveira J. Exercise training improves diastolic function in heart failure patients. *Med Sci Sports Exerc* 2012; **44**: 776–785.
22. Anagnostakou V, Chatzimichail K, Dimopoulos S, Karatzanos E, Papazachou O, Tasoulis A, Anastasiou-Nana M, Roussos C, Nanas S. Effects of interval cycle training with or without strength training on vascular reactivity in heart failure patients. *J Card Fail* 2011; **17**: 585–591.
23. Andryukhin A, Frolova E, Vaes B, Degryse J. The impact of a nurse-led care programme on events and physical and psychosocial parameters in patients with heart failure with preserved ejection fraction: a randomized clinical trial in primary care in Russia. *Eur J Gen Pract* 2010; **16**: 205–214.
24. Angadi SS, Mookadam F, Lee CD, Tucker WJ, Haykowsky MJ, Gaesser GA. High-intensity interval training vs. moderate-intensity continuous exercise training in heart failure with preserved ejection fraction: a pilot study. *J Appl Physiol (1985)* 2015; **119**: 753–758.
25. Antonicelli R, Spazzafumo L, Scalvini S, Olivieri F, Matassini MV, Parati G, Del Sindaco D, Gallo R, Lattanzio F. Exercise: a "new drug" for elderly patients with chronic heart failure. *Aging* 2016; **8**: 860–872.
26. Antunes-Correa LM, Nobre TS, Groehs RV, Alves MJ, Fernandes T, Couto GK, Rondon MU, Oliveira P, Lima M, Mathias W, Brum PC, Mady C, Almeida DR, Rossoni LV, Oliveira EM, Middlekauff HR, Negrao CE. Molecular basis for the improvement in muscle metaboreflex and mechanoreflex control in exercise-trained humans with chronic heart failure. *Am J Physiol Heart Circ Physiol* 2014; **307**: H1655–H1666.
27. Antunes-Correa LM, Trevizan PF, Bacurau AVN, Ferreira-Santos L, Gomes JLP, Urias U, Oliveira PA, Alves M, de Almeida DR, Brum PC, Oliveira EM, Hajjar L, Kalil Filho R, Negrão CE. Effects of aerobic and inspiratory training on skeletal muscle microRNA-1 and downstream-associated pathways in patients with heart failure. *J Cachexia Sarcopenia Muscle* 2020; **11**: 89–102.
28. Austin J, Williams R, Ross L, Moseley L, Hutchison S. Randomised controlled trial of cardiac rehabilitation in elderly patients with heart failure. *Eur J Heart Fail* 2005; **7**: 411–417.
29. Barker K, Holland AE, Lee AL, Haines T, Ritchie K, Boote C, Saliba J, Lowe S, Pazsa F, Thomas L, Turczyniak M, Skinner EH. Multimorbidity rehabilitation versus disease-specific rehabilitation in people with chronic diseases: a pilot randomized controlled trial. *Pilot Feasibility Stud* 2018; **4**: 181.
30. Barnard KL, Adams KJ, Swank AM, Kaelin M, Kushnik MR, Denny DM. Combined high-intensity strength and aerobic training in patients with congestive heart failure. *J Strength Cond Res* 2000; **14**: 383–388.
31. Beckers PJ, Denollet J, Possemiers NM, Wuyts FL, Vrints CJ, Conraads VM. Combined endurance-resistance training vs. endurance training in patients with chronic heart failure: a prospective randomized study. *Eur Heart J* 2008; **29**: 1858–1866.
32. Belardinelli R, Capestro F, Misiani A, Scipione P, Georgiou D. Moderate exercise training improves functional capacity, quality of life, and endothelium-dependent vasodilation in chronic heart failure patients with implantable cardioverter defibrillators and cardiac resynchronization therapy. *Eur J Cardiovasc Prev Rehabil* 2006; **13**: 818–825.
33. Belardinelli R, Lacalaprice F, Faccenda E, Purcaro A, Perna G. Effects of short-term moderate exercise training on sexual function in male patients with chronic stable heart failure. *Int J Cardiol* 2005; **101**: 83–90.
34. Beniaminovitz A, Lang CC, LaManca J, Mancini DM. Selective low-level leg muscle training alleviates dyspnea in patients with heart failure. *J Am Coll Cardiol* 2002; **40**: 1602–1608.
35. Bernocchi P, Vitacca M, La Rovere MT, Volterrani M, Galli T, Baratti D, Paneroni M, Campolongo G, Sposato B, Scalvini S. Home-based telerehabilitation in older patients with chronic obstructive pulmonary disease and heart failure: a randomised controlled trial. *Age Ageing* 2018; **47**: 82–88.
36. Besnier F, Labrunee M, Richard L, Faggianelli F, Kerros H, Soukarie L, Bousquet M, Garcia JL, Pathak A, Gales C, Guiraud T, Senard JM. Short-term effects of a 3-week interval training program on heart rate variability in chronic heart failure. A randomised controlled trial. *Ann Phys Rehabil Med* 2019; **62**: 321–328.
37. Besson D, Joussain C, Gremeaux V, Morisset C, Laurent Y, Casillas JM, Laroche D. Eccentric training in chronic heart failure: feasibility and functional effects. Results of a comparative study. *Ann Phys Rehabil Med* 2013; **56**: 30–40.
38. Bittencourt HS, Cruz CG, David BC, Rodrigues E Jr, Abade CM, Junior RA, Carvalho VO, Dos Reis FBF, Gomes NM. Addition of non-invasive

ventilatory support to combined aerobic and resistance training improves dyspnea and quality of life in heart failure patients: a randomized controlled trial. *Clin Rehabil* 2017; **31**: 1508–1515.
39. Bocalini DS, dos Santos L, Serra AJ. Physical exercise improves the functional capacity and quality of life in patients with heart failure. *Clinics (Sao Paulo)* 2008; **63**: 437–442.
40. Borland M, Rosenkvist A, Cider A. A group-based exercise program did not improve physical activity in patients with chronic heart failure and comorbidity: a randomized controlled trial. *J Rehabil Med* 2014; **46**: 461–467.
41. Casillas JM, Besson D, Hannequin A, Gremeaux V, Morisset C, Tordi N, Laurent Y, Laroche D. Effects of an eccentric training personalized by a low rate of perceived exertion on the maximal capacities in chronic heart failure: a randomized controlled trial. *Eur J Phys Rehabil Med* 2016; **52**: 159–168.
42. Chen Y-W, Wang C-Y, Lai Y-H, Liao Y-C, Wen Y-K, Chang S-T, Huang J-L, Wu T-J. Home-based cardiac rehabilitation improves quality of life, aerobic capacity, and readmission rates in patients with chronic heart failure. *Medicine* 2018; **97**.
43. Chrysohoou C, Angelis A, Tsitsinakis G, Spetsioti S, Nasis I, Tsiachris D, Rapakoulias P, Pitsavos C, Koulouris NG, Vogiatzis I, Dimitris T. Cardiovascular effects of high-intensity interval aerobic training combined with strength exercise in patients with chronic heart failure. A randomized phase III clinical trial. *Int J Cardiol* 2015; **179**: 269–274.
44. Collins E, Langbein WE, Dilan-Koetje J, Bammert C, Hanson K, Reda D, Edwards L. Effects of exercise training on aerobic capacity and quality of life in individuals with heart failure. *Heart Lung* 2004; **33**: 154–161.
45. Conraads VM, Vanderheyden M, Paelinck B, Verstreken S, Blankoff I, Miljoen H, De Sutter J, Beckers P. The effect of endurance training on exercise capacity following cardiac resynchronization therapy in chronic heart failure patients: a pilot trial. *Eur J Cardiovasc Prev Rehabil* 2007; **14**: 99–106.
46. Corvera-Tindel T, Doering LV, Woo MA, Khan S, Dracup K. Effects of a home walking exercise program on functional status and symptoms in heart failure. *Am Heart J* 2004; **147**: 339–346.
47. Cowie A, Thow MK, Granat MH, Mitchell SL. A comparison of home and hospital-based exercise training in heart failure: immediate and long-term effects upon physical activity level. *Eur J Cardiovasc Prev Rehabil* 2011; **18**: 158–166.
48. Davidson PM, Cockburn J, Newton PJ, Webster JK, Betihavas V, Howes L, Owensby DO. Can a heart failure-specific cardiac rehabilitation program decrease hospitalizations and improve outcomes in high-risk patients? *Eur J Cardiovasc Prev Rehabil* 2010; **17**: 393–402.
49. de Mello Franco FG, Santos AC, Rondon MU, Trombetta IC, Strunz C, Braga AM, Middlekauff H, Negrao CE, Pereira Barretto AC. Effects of home-based exercise training on neurovascular control in patients with heart failure. *Eur J Heart Fail* 2006; **8**: 851–855.
50. Dehkordi Hassanpour A, Khaledi FA. Effect of exercise training on the quality of life and echocardiography parameter of systolic function in patients with chronic heart failure: a randomized trial. *Asian J Sports Med* 2015; **6**: e22643.
51. Deka P, Pozehl B, Williams MA, Norman JF, Khazanchi D, Pathak D. MOVE-HF: an internet-based pilot study to improve adherence to exercise in patients with heart failure. *Eur J Cardiovasc Nurs* 2019; **18**: 122–131.
52. Deley G, Kervio G, Verges B, Hannequin A, Petitdant MF, Salmi-Belmihoub S, Grassi B, Casillas JM. Comparison of low-frequency electrical myostimulation and conventional aerobic exercise training in patients with chronic heart failure. *Eur J Cardiovasc Prev Rehabil* 2005; **12**: 226–233.
53. Dimopoulos S, Anastasiou-Nana M, Sakellariou D, Drakos S, Kapsimalakou S, Maroulidis G, Roditis P, Papazachou O, Vogiatzis I, Roussos C, Nanas S. Effects of exercise rehabilitation program on heart rate recovery in patients with chronic heart failure. *Eur J Cardiovasc Prev Rehabil* 2006; **13**: 67–73.
54. Dobsak P, Novakova M, Fiser B, Siegelova J, Balcarkova P, Spinarova L, Vitovec J, Minami N, Nagasaka M, Kohzuki M, Yambe T, Imachi K, Nitta S, Eicher JC, Wolf JE. Electrical stimulation of skeletal muscles. An alternative to aerobic exercise training in patients with chronic heart failure? *Int Heart J* 2006; **47**: 441–453.
55. Dobsak P, Tomandl J, Spinarova L, Vitovec J, Dusek L, Novakova M, Jarkovsky J, Krejci J, Hude P, Honek T, Siegelova J, Homolka P. Effects of neuromuscular electrical stimulation and aerobic exercise training on arterial stiffness and autonomic functions in patients with chronic heart failure. *Artif Organs* 2012; **36**: 920–930.
56. Donelli da Silveira A, Beust de Lima J, da Silva Piardi D, Dos Santos Macedo D, Zanini M, Nery R, Laukkanen JA, Stein R. High-intensity interval training is effective and superior to moderate continuous training in patients with heart failure with preserved ejection fraction: a randomized clinical trial. *Eur J Prev Cardiol* 2020; **27**: 1733–1743.
57. Dos Santos MR, Sayegh AL, Bacurau AV, Arap MA, Brum PC, Pereira RM, Takayama L, Barretto AC, Negrão CE, Alves MJ. Effect of exercise training and testosterone replacement on skeletal muscle wasting in patients with heart failure with testosterone deficiency. *Mayo Clin Proc* 2016; **91**: 575–586.
58. Dracup K, Evangelista LS, Hamilton MA, Erickson V, Hage A, Moriguchi J, Canary C, MacLellan WR, Fonarow GC. Effects of a home-based exercise program on clinical outcomes in heart failure. *Am Heart J* 2007; **154**: 877–883.
59. Edelmann F, Gelbrich G, Dungen HD, Frohling S, Wachter R, Stahrenberg R, Binder L, Topper A, Lashki DJ, Schwarz S, Herrmann-Lingen C, Loffler M, Hasenfuss G, Halle M, Pieske B. Exercise training improves exercise capacity and diastolic function in patients with heart failure with preserved ejection fraction: results of the Ex-DHF (Exercise training in Diastolic Heart Failure) pilot study. *J Am Coll Cardiol* 2011; **58**: 1780–1791.
60. Evans RA, Singh SJ, Collier R, Loke I, Steiner MC, Morgan MD. Generic, symptom based, exercise rehabilitation; integrating patients with COPD and heart failure. *Respir Med* 2010; **104**: 1473–1481.
61. Fabri T, Catai AM, Ribeiro FHO, Junior JAA, Milan-Mattos J, Rossi DAA, Coneglian RC, Borra RC, Bazan SGZ, Hueb JC, Matsubara BB, Roscani MG. Impact of a supervised twelve-week combined physical training program in heart failure patients: a randomized trial. *Cardiol Res Pract* 2019; **2019**: 1718281.
62. Feiereisen P, Delagardelle C, Vaillant M, Lasar Y, Beissel J. Is strength training the more efficient training modality in chronic heart failure? *Med Sci Sports Exerc* 2007; **39**: 1910–1917.
63. Fernandes-Silva MM, Guimaraes 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.
64. Flynn KE, Pina IL, Whellan DJ, Lin L, Blumenthal JA, Ellis SJ, Fine LJ, Howlett JG, Keteyian SJ, Kitzman DW, Kraus WE, Miller NH, Schulman KA, Spertus JA, O'Connor CM, Weinfurt KP, Investigators H-A. Effects of exercise training on health status in patients with chronic heart failure: HF-ACTION randomized controlled trial. *JAMA* 2009; **301**: 1451–1459.
65. Fraga R, Franco FG, Roveda F, de Matos LN, Braga AM, Rondon MU, Rotta DR, Brum PC, Barretto AC, Middlekauff HR, Negrao CE. Exercise training reduces sympathetic nerve activity in heart failure patients treated

with carvedilol. *Eur J Heart Fail* 2007; **9**: 630–636.
66. Freyssin C, Verkindt C, Prieur F, Benaich P, Maunier S, Blanc P. Cardiac rehabilitation in chronic heart failure: effect of an 8-week, high-intensity interval training versus continuous training. *Arch Phys Med Rehabil* 2012; **93**: 1359–1364.
67. Fu TC, Wang CH, Lin PS, Hsu CC, Cherng WJ, Huang SC, Liu MH, Chiang CL, Wang JS. Aerobic interval training improves oxygen uptake efficiency by enhancing cerebral and muscular hemodynamics in patients with heart failure. *Int J Cardiol* 2013; **167**: 41–50.
68. Gary RA, Cress ME, Higgins MK, Smith AL, Dunbar SB. A combined aerobic and resistance exercise program improves physical functional performance in patients with heart failure: a pilot study. *J Cardiovasc Nurs* 2012; **27**: 418–430.
69. Georgantas A, Dimopoulos S, Tasoulis A, Karatzanos E, Pantsios C, Agapitou V, Ntalianis A, Roditis P, Terrovitis J, Nanas S. Beneficial effects of combined exercise training on early recovery cardiopulmonary exercise testing indices in patients with chronic heart failure. *J Cardiopulm Rehabil Prev* 2014; **34**: 378–385.
70. Giannuzzi P, Temporelli PL, Corra U, Tavazzi L, Group E-CS. Antiremodeling effect of long-term exercise training in patients with stable chronic heart failure: results of the Exercise in Left Ventricular Dysfunction and Chronic Heart Failure (ELVD-CHF) Trial. *Circulation* 2003; **108**: 554–559.
71. Gielen S, Adams V, Mobius-Winkler S, Linke A, Erbs S, Yu J, Kempf W, Schubert A, Schuler G, Hambrecht R. Anti-inflammatory effects of exercise training in the skeletal muscle of patients with chronic heart failure. *J Am Coll Cardiol* 2003; **42**: 861–868.
72. Guazzi M, Reina G, Tumminello G, Guazzi MD. Improvement of alveolar-capillary membrane diffusing capacity with exercise training in chronic heart failure. *J Appl Physiol (1985)* 2004; **97**: 1866–1873.
73. Harris S, LeMaitre JP, Mackenzie G, Fox KA, Denvir MA. A randomised study of home-based electrical stimulation of the legs and conventional bicycle exercise training for patients with chronic heart failure. *Eur Heart J* 2003; **24**: 871–878.
74. Hornikx M, Buys R, Cornelissen V, Deroma M, Goetschalckx K. Effectiveness of high intensity interval training supplemented with peripheral and inspiratory resistance training in chronic heart failure: a pilot study. *Acta Cardiol* 2020; **75**: 339–347.
75. Hwang R, Bruning J, Morris NR, Mandrusiak A, Russell T. Home-based telerehabilitation is not inferior to a centre-based program in patients with chronic heart failure: a randomised trial. *J Physiother* 2017; **63**: 101–107.
76. Iellamo F, Caminiti G, Sposato B, Vitale C, Massaro M, Rosano G, Volterrani M. Effect of High-Intensity interval training versus moderate continuous training on 24-h blood pressure profile and insulin resistance in patients with chronic heart failure. *Intern Emerg Med* 2014; **9**: 547–552.
77. Iellamo F, Manzi V, Caminiti G, Sposato B, Massaro M, Cerrito A, Rosano G, Volterrani M. Dose-response relationship of baroreflex sensitivity and heart rate variability to individually-tailored exercise training in patients with heart failure. *Int J Cardiol* 2013; **166**: 334–339.
78. Iliou MC, Corone S, Gellen B, Denolle T, Roche F, Nelson AC, Darne C. Is ventilatory therapy combined with exercise training effective in patients with heart failure and sleep-disordered breathing? Results of a randomized trial during a cardiac rehabilitation programme (SATELIT-HF). *Arch Cardiovasc Dis* 2018; **111**: 573–581.
79. Iliou MC, Verges-Patois B, Pavy B, Charles-Nelson A, Monpere C, Richard R, Verdier JC, the C-HFsg. Effects of combined exercise training and electromyostimulation treatments in chronic heart failure: a prospective multicentre study. *Eur J Prev Cardiol* 2017; **24**: 1274–1282.
80. Jonsdottir S, Andersen KK, Sigurosson AF, Sigurosson SB. The effect of physical training in chronic heart failure. *Eur J Heart Fail* 2006; **8**: 97–101.
81. Kaltsatou AC, Kouidi EI, Anifanti MA, Douka SI, Deligiannis AP. Functional and psychosocial effects of either a traditional dancing or a formal exercising training program in patients with chronic heart failure: a comparative randomized controlled study. *Clin Rehabil* 2014; **28**: 128–138.
82. Karapolat H, Demir E, Bozkaya YT, Eyigor S, Nalbantgil S, Durmaz B, Zoghi M. Comparison of hospital-based versus home-based exercise training in patients with heart failure: effects on functional capacity, quality of life, psychological symptoms, and hemodynamic parameters. *Clin Res Cardiol* 2009; **98**: 635–642.
83. Kawauchi TS, Umeda IIK, Braga LM, Mansur AP, Rossi-Neto JM, Guerra de Moraes Rego Sousa A, Hirata MH, Cahalin LP, Nakagawa NK. Is there any benefit using low-intensity inspiratory and peripheral muscle training in heart failure? A randomized clinical trial. *Clin Res Cardiol* 2017; **106**: 676–685.
84. Keast ML, Slovinec D'Angelo ME, Nelson CR, Turcotte SE, McDonnell LA, Nadler RE, Reed JL, Pipe AL, Reid RD. Randomized trial of Nordic walking in patients with moderate to severe heart failure. *Can J Cardiol* 2013; **29**: 1470–1476.
85. Keyhani D, Kargarfard M, Sarrafzadegan N, Sadeghi M. Autonomic function change following a supervised exercise program in patients with congestive heart failure. *ARYA Atheroscler* 2013; **9**: 150–156.
86. Kitzman DW, Haykowsky MJ, Kraus W. Diet and exercise for obese patients with heart failure—reply. *JAMA* 2016; **315**: 2619–2620.
87. Kobayashi N, Tsuruya Y, Iwasawa T, Ikeda N, Hashimoto S, Yasu T, Ueba H, Kubo N, Fujii M, Kawakami M, Saito M. Exercise training in patients with chronic heart failure improves endothelial function predominantly in the trained extremities. *Circ J* 2003; **67**: 505–510.
88. Koufaki P, Mercer TH, George KP, Nolan J. Low-volume high-intensity interval training vs continuous aerobic cycling in patients with chronic heart failure: a pragmatic randomised clinical trial of feasibility and effectiveness. *J Rehabil Med* 2014; **46**: 348–356.
89. Koukouvou G, Kouidi E, Iacovides A, Konstantinidou E, Kaprinis G, Deligiannis A. Quality of life, psychological and physiological changes following exercise training in patients with chronic heart failure. *J Rehabil Med* 2004; **36**: 36–41.
90. Kucio C, Stastny P, Leszczynska-Bolewska B, Engelmann M, Kucio E, Uhlir P, Stania M, Polak A. Exercise-based cardiac rehabilitation with and without neuromuscular electrical stimulation and its effect on exercise tolerance and life quality of persons with chronic heart failure. *J Hum Kinet* 2018; **65**: 151–164.
91. Kulcu DG, Kurtais Y, Tur BS, Gulec S, Seckin B. The effect of cardiac rehabilitation on quality of life, anxiety and depression in patients with congestive heart failure. A randomized controlled trial, short-term results. *Eura Medicophys* 2007; **43**: 489–497.
92. Lan NSR, Lam K, Naylor LH, Green DJ, Minaee NS, Dias P, Maiorana AJ. The impact of distinct exercise training modalities on echocardiographic measurements in patients with heart failure with reduced ejection fraction. *J Am Soc Echocardiogr* 2020; **33**: 148–156.
93. Lang CC, Smith K, Wingham J, Eyre V, Greaves CJ, Warren FC, Green C, Jolly K, Davis RC, Doherty PJ, Miles J, Britten N, Abraham C, Van Lingen R, Singh SJ, Paul K, Hillsdon M, Sadler S, Hayward C, Dalal HM, Taylor RS. A randomised controlled trial of a facilitated home-based rehabilitation intervention in patients with heart failure with preserved ejection fraction and their caregivers: the REACH-HFpEF Pilot Study. *BMJ Open* 2018; **8**: e019649.
94. Lans C, Cider Å, Nylander E, Brudin L. Peripheral muscle training with resistance exercise bands in patients with chronic heart failure. Long-term effects on walking distance and quality of life;

a pilot study. *ESC Heart Fail* 2018; **5**: 241–248.
95. Laoutaris ID, Adamopoulos S, Manginas A, Panagiotakos DB, Kallistratos MS, Doulaptsis C, Kouloubinis A, Voudris V, Pavlides G, Cokkinos DV, Dritsas A. Benefits of combined aerobic/resistance/inspiratory training in patients with chronic heart failure. A complete exercise model? A prospective randomised study. *Int J Cardiol* 2013; **167**: 1967–1972.
96. LeMaitre JP, Harris S, Fox KA, Denvir M. Change in circulating cytokines after 2 forms of exercise training in chronic stable heart failure. *Am Heart J* 2004; **147**: 100–105.
97. LeMaitre JP, Harris S, Hannan J, Fox KA, Denvir MA. Maximum oxygen uptake corrected for skeletal muscle mass accurately predicts functional improvements following exercise training in chronic heart failure. *Eur J Heart Fail* 2006; **8**: 243–248.
98. Linke A, Adams V, Schulze PC, Erbs S, Gielen S, Fiehn E, Mobius-Winkler S, Schubert A, Schuler G, Hambrecht R. Antioxidative effects of exercise training in patients with chronic heart failure: increase in radical scavenger enzyme activity in skeletal muscle. *Circulation* 2005; **111**: 1763–1770.
99. Maiorana AJ, Naylor LH, Exterkate A, Swart A, Thijssen DH, Lam K, O'Driscoll G, Green DJ. The impact of exercise training on conduit artery wall thickness and remodeling in chronic heart failure patients. *Hypertension* 2011; **57**: 56–62.
100. Mandic S, Tymchak W, Kim D, Daub B, Quinney HA, Taylor D, Al-Kurtass S, Haykowsky MJ. Effects of aerobic or aerobic and resistance training on cardiorespiratory and skeletal muscle function in heart failure: a randomized controlled pilot trial. *Clin Rehabil* 2009; **23**: 207–216.
101. McGuire R, Honaker J, Pozehl B, Hertzog M. BASIC training: a pilot study of balance/strengthening exercises in heart failure. *Rehabil Nurs* 2020; **45**: 30–38.
102. McKelvie RS, Teo KK, Roberts R, McCartney N, Humen D, Montague T, Hendrican K, Yusuf S. Effects of exercise training in patients with heart failure: the Exercise Rehabilitation Trial (EXERT). *Am Heart J* 2002; **144**: 23–30.
103. Munch GW, Rosenmeier JB, Petersen M, Rinnov AR, Iepsen UW, Pedersen BK, Mortensen SP. Comparative effectiveness of low-volume time-efficient resistance training versus endurance training in patients with heart failure. *J Cardiopulm Rehabil Prev* 2018; **38**: 175–181.
104. Myers J, Gademan M, Brunner K, Kottman W, Boesch C, Dubach P. Effects of high-intensity training on indices of ventilatory efficiency in chronic heart failure. *J Cardiopulm Rehabil Prev* 2012; **32**: 9–16.
105. Nilsson BB, Westheim A, Risberg MA. Effects of group-based high-intensity aerobic interval training in patients with chronic heart failure. *Am J Cardiol* 2008; **102**: 1361–1365.
106. Nobre TS, Antunes-Correa LM, Groehs RV, Alves MJ, Sarmento AO, Bacurau AV, Urias U, Alves GB, Rondon MU, Brum PC, Martinelli M, Middlekauff HR, Negrao CE. Exercise training improves neurovascular control and calcium cycling gene expression in patients with heart failure with cardiac resynchronization therapy. *Am J Physiol Heart Circ Physiol* 2016; **311**: H1180–H1188.
107. Oka RK, De Marco T, Haskell WL, Botvinick E, Dae MW, Bolen K, Chatterjee K. Impact of a home-based walking and resistance training program on quality of life in patients with heart failure. *Am J Cardiol* 2000; **85**: 365–369.
108. Ozasa N, Morimoto T, Bao B, Shioi T, Kimura T. Effects of machine-assisted cycling on exercise capacity and endothelial function in elderly patients with heart failure. *Circ J* 2012; **76**: 1889–1894.
109. Palevo G, Keteyian SJ, Kang M, Caputo JL. Resistance exercise training improves heart function and physical fitness in stable patients with heart failure. *J Cardiopulm Rehabil Prev* 2009; **29**: 294–298.
110. Parnell MM, Holst DP, Kaye DM. Exercise training increases arterial compliance in patients with congestive heart failure. *Clin Sci (Lond)* 2002; **102**: 1–7.
111. Parnell MM, Holst DP, Kaye DM. Augmentation of endothelial function following exercise training is associated with increased L-arginine transport in human heart failure. *Clin Sci (Lond)* 2005; **109**: 523–530.
112. Passino C, Del Ry S, Severino S, Gabutti A, Prontera C, Clerico A, Giannessi D, Emdin M. C-type natriuretic peptide expression in patients with chronic heart failure: effects of aerobic training. *Eur J Cardiovasc Prev Rehabil* 2008; **15**: 168–172.
113. Peng X, Su Y, Hu Z, Sun X, Li X, Dolansky MA, Qu M, Hu X. Home-based telehealth exercise training program in Chinese patients with heart failure: a randomized controlled trial. *Medicine* 2018; **97**: e12069.
114. Pineda-Juárez JA, Sánchez-Ortiz NA, Castillo-Martínez L, Orea-Tejeda A, Cervantes-Gaytán R, Keirns-Davis C, Pérez-Ocampo C, Quiroz-Bautista K, Tenorio-Dupont M, Ronquillo-Martínez A. Changes in body composition in heart failure patients after a resistance exercise program and branched chain amino acid supplementation. *Clin Nutr (Edinburgh, Scotland)* 2016; **35**: 41–47.
115. Piotrowicz E, Baranowski R, Bilinska M, Stepnowska M, Piotrowska M, Wojcik A, Korewicki J, Chojnowska L, Malek LA, Klopotowski M, Piotrowski W, Piotrowicz R. A new model of home-based telemonitored cardiac rehabilitation in patients with heart failure: effectiveness, quality of life, and adherence. *Eur J Heart Fail* 2010; **12**: 164–171.
116. Piotrowicz E, Pencina MJ, Opolski G, Zareba W, Banach M, Kowalik I, Orzechowski P, Szalewska D, Pluta S, Glówczynska R, Irzmanski R, Oreziak A, Kalarus Z, Lewicka E, Cacko A, Mierzynska A, Piotrowicz R. Effects of a 9-week hybrid comprehensive telerehabilitation program on long-term outcomes in patients with heart failure: the telerehabilitation in heart failure patients (TELEREH-HF) randomized clinical trial. *JAMA Cardiol* 2020; **5**: 300–308.
117. Piotrowicz E, Zieliński T, Bodalski R, Rywik T, Dobraszkiewicz-Wasilewska B, Sobieszczańska-Małek M, Stepnowska M, Przybylski A, Browarek A, Szumowski Ł, Piotrowski W, Piotrowicz R. Home-based telemonitored Nordic walking training is well accepted, safe, effective and has high adherence among heart failure patients, including those with cardiovascular implantable electronic devices: a randomised controlled study. *Eur J Prev Cardiol* 2015; **22**: 1368–1377.
118. Pourhabib AFZ, Nasiri M, Aborotan S. Effects of a group-based aerobic and resistance exercise program on physiological-psychological adaptation in elderly with heart failure. *J Clin Gerontol Geriatr* 2018; **9**: 59–66.
119. Pozehl B, Duncan K, Hertzog M, Norman JF. Heart failure exercise and training camp: effects of a multicomponent exercise training intervention in patients with heart failure. *Heart Lung* 2010; **39**: S1–S13.
120. Pozehl B, Duncan K, Krueger S, VerMaas P. Adjunctive effects of exercise training in heart failure patients receiving maximum pharmacologic therapy. *Prog Cardiovasc Nurs* 2003; **18**: 177–183.
121. Prescott E, Hjardem-Hansen R, Dela F, Orkild B, Teisner AS, Nielsen H. Effects of a 14-month low-cost maintenance training program in patients with chronic systolic heart failure: a randomized study. *Eur J Cardiovasc Prev Rehabil* 2009; **16**: 430–437.
122. Prince SA, Wooding E, Mielniczuk L, Pipe AL, Chan KL, Keast ML, Harris J, Tulloch HE, Mark AE, Cotie LM, Wells GA, Reid RD. Nordic walking and standard exercise therapy in patients with chronic heart failure: a randomised controlled trial comparison. *Eur J Prev Cardiol* 2019; **26**: 1790–1794.
123. Pu CT, Johnson MT, Forman DE, Hausdorff JM, Roubenoff R, Foldvari M, Fielding RA, Singh MA. Randomized trial of progressive resistance training to counteract the myopathy

of chronic heart failure. *J Appl Physiol (1985)* 2001; **90**: 2341–2350.
124. Redwine LS, Wilson K, Pung MA, Chinh K, Rutledge T, Mills PJ, Smith B. A randomized study examining the effects of mild-to-moderate group exercises on cardiovascular, physical, and psychological well-being in patients with heart failure. *J Cardiopulm Rehabil Prev* 2019; **39**: 403–408.
125. Ricca-Mallada R, Migliaro ER, Piskorski J, Guzik P. Exercise training slows down heart rate and improves deceleration and acceleration capacity in patients with heart failure. *J Electrocardiol* 2012; **45**: 214–219.
126. Ricca-Mallada R, Migliaro ER, Silvera G, Chiappella L, Frattini R, Ferrando-Castagnetto F. Functional outcome in chronic heart failure after exercise training: possible predictive value of heart rate variability. *Ann Phys Rehabil Med* 2017; **60**: 87–94.
127. Roditis P, Dimopoulos S, Sakellariou D, Sarafoglou S, Kaldara E, Venetsanakos J, Vogiatzis J, Anastasiou-Nana M, Roussos C, Nanas S. The effects of exercise training on the kinetics of oxygen uptake in patients with chronic heart failure. *Eur J Cardiovasc Prev Rehabil* 2007; **14**: 304–311.
128. Roveda F, Middlekauff HR, Rondon MU, Reis SF, Souza M, Nastari L, Barretto AC, Krieger EM, Negrao CE. The effects of exercise training on sympathetic neural activation in advanced heart failure: a randomized controlled trial. *J Am Coll Cardiol* 2003; **42**: 854–860.
129. Sabelis LW, Senden PJ, Fijnheer R, de Groot PG, Huisveld IA, Mosterd WL, Zonderland ML. Endothelial markers in chronic heart failure: training normalizes exercise-induced vWF release. *Eur J Clin Invest* 2004; **34**: 583–589.
130. Sadek Z, Salami A, Youness M, Awada C, Hamade M, Joumaa WH, Ramadan W, Ahmaidi S. A randomized controlled trial of high-intensity interval training and inspiratory muscle training for chronic heart failure patients with inspiratory muscle weakness. *Chronic Illn* 2020: 1742395320920700.
131. Safiyari-Hafizi H, Taunton J, Ignaszewski A, Warburton DE. The health benefits of a 12-week home-based interval training cardiac rehabilitation program in patients with heart failure. *Can J Cardiol* 2016; **32**: 561–567.
132. Sandri M, Kozarez I, Adams V, Mangner N, Hollriegel R, Erbs S, Linke A, Mobius-Winkler S, Thiery J, Kratzsch J, Teupser D, Mende M, Hambrecht R, Schuler G, Gielen S. Age-related effects of exercise training on diastolic function in heart failure with reduced ejection fraction: the Leipzig Exercise Intervention in Chronic Heart Failure and Aging (LEICA) Diastolic Dysfunction Study. *Eur Heart J* 2012; **33**: 1758–1768.
133. Santa-Clara H, Abreu A, Melo X, Santos V, Cunha P, Oliveira M, Pinto R, Carmo MM, Fernhall B. High-intensity interval training in cardiac resynchronization therapy: a randomized control trial. *Eur J Appl Physiol* 2019; **119**: 1757–1767.
134. Santos JM, Kowatsch I, Tsutsui JM, Negrao CE, Canavesi N, Carvalho Frimm C, Mady C, Ramires JA, Mathias W Jr. Effects of exercise training on myocardial blood flow reserve in patients with heart failure and left ventricular systolic dysfunction. *Am J Cardiol* 2010; **105**: 243–248.
135. Servantes DM, Javaheri S, Kravchychyn ACP, Storti LJ, Almeida DR, de Mello MT, Cintra FD, Tufik S, Bittencourt L. Effects of exercise training and CPAP in patients with heart failure and OSA: a preliminary study. *Chest* 2018; **154**: 808–817.
136. Servantes DM, Pelcerman A, Salvetti XM, Salles AF, de Albuquerque PF, de Salles FC, Lopes C, de Mello MT, Almeida DR, Filho JA. Effects of home-based exercise training for patients with chronic heart failure and sleep apnoea: a randomized comparison of two different programmes. *Clin Rehabil* 2012; **26**: 45–57.
137. Shaltout HA, Eggebeen J, Marsh AP, Brubaker PH, Laurienti PJ, Burdette JH, Basu S, Morgan A, Dos Santos PC, Norris JL, Morgan TM, Miller GD, Rejeski WJ, Hawfield AT, Diz DI, Becton JT, Kim-Shapiro DB, Kitzman DW. Effects of supervised exercise and dietary nitrate in older adults with controlled hypertension and/or heart failure with preserved ejection fraction. *Nitric Oxide* 2017; **69**: 78–90.
138. Shoemaker MJ, Oberholtzer NL, Jongekrijg LE, Bowen TE, Cartwright K, Hanson K, Serba D, Dickinson MG, Kowalk A. Exercise- and psychosocial-based interventions to improve daily activity in heart failure: a pilot study. *Home Health Care Manag Pract* 2017; **29**: 111–120.
139. Smart N. Exercise training for heart failure patients with and without systolic dysfunction: an evidence-based analysis of how patients benefit. *Cardiol Res Pract* 2010; **2011**: 121–129.
140. Smart NA, Steele M. A comparison of 16 weeks of continuous vs intermittent exercise training in chronic heart failure patients. *Congest Heart Fail* 2012; **18**: 205–211.
141. Smolis-Bak E, Dabrowski R, Piotrowicz E, Chwyczko T, Dobraszkiewicz-Wasilewska B, Kowalik I, Kazimierska B, Jedrzejczyk B, Smolis R, Gepner K, Maciag A, Sterlinski M, Szwed H. Hospital-based and telemonitoring guided home-based training programs: effects on exercise tolerance and quality of life in patients with heart failure (NYHA class III) and cardiac resynchronization therapy. A randomized, prospective observation. *Int J Cardiol* 2015; **199**: 442–447.
142. Soska V, Dobsak P, Pohanka M, Spinarova L, Vitovec J, Krejci J, Hude P, Homolka P, Novakova M, Eicher JC, Wolf JE, Dusek L, Siegelova J. Exercise training combined with electromyostimulation in the rehabilitation of patients with chronic heart failure: a randomized trial. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub* 2014; **158**: 98–106.
143. Spee RF, Niemeijer VM, Schoots T, Tuinenburg A, Houthuizen P, Wijn PF, Doevendans PA, Kemps HM. High intensity interval training after cardiac resynchronization therapy: an explorative randomized controlled trial. *Int J Cardiol* 2020; **299**: 169–174.
144. Steele BG, Dougherty CM, Burr RL, Colwell IG, Hunziker J. A feasibility trial of two rehabilitation models in severe cardiopulmonary illness. *Rehabil Nurs* 2019; **44**: 130–140.
145. Stevens AL, Hansen D, Herbots L, Wens I, Creemers A, Dendale P, Eijnde BO. Exercise training improves insulin release during glucose tolerance testing in stable chronic heart failure patients. *J Cardiopulm Rehabil Prev* 2015; **35**: 37–46.
146. Stout M, Tew GA, Doll H, Zwierska I, Woodroofe N, Channer KS, Saxton JM. Testosterone therapy during exercise rehabilitation in male patients with chronic heart failure who have low testosterone status: a double-blind randomized controlled feasibility study. *Am Heart J* 2012; **164**: 893–901.
147. Tanaka Y, Takarada Y. The impact of aerobic exercise training with vascular occlusion in patients with chronic heart failure. *ESC Heart Fail* 2018; **5**: 586–591.
148. Tasoulis A, Papazachou O, Dimopoulos S, Gerovasili V, Karatzanos E, Kyprianou T, Drakos S, Anastasiou-Nana M, Roussos C, Nanas S. Effects of interval exercise training on respiratory drive in patients with chronic heart failure. *Respir Med* 2010; **104**: 1557–1565.
149. Tyni-Lenne R, Dencker K, Gordon A, Jansson E, Sylven C. Comprehensive local muscle training increases aerobic working capacity and quality of life and decreases neurohormonal activation in patients with chronic heart failure. *Eur J Heart Fail* 2001; **3**: 47–52.
150. van den Berg-Emons R, Balk A, Bussmann H, Stam H. Does aerobic training lead to a more active lifestyle and improved quality of life in patients with chronic heart failure? *Eur J Heart Fail* 2004; **6**: 95–100.
151. Wall HK, Ballard J, Troped P, Njike VY, Katz DL. Impact of home-based, supervised exercise on congestive heart failure. *Int J Cardiol* 2010; **145**: 267–270.
152. Williams AD, Carey MF, Selig S, Hayes A, Krum H, Patterson J, Toia D, Hare DL. Circuit resistance training in

chronic heart failure improves skeletal muscle mitochondrial ATP production rate—a randomized controlled trial. *J Card Fail* 2007; **13**: 79–85.
153. Winkelmann ER, Chiappa GR, Lima CO, Viecili PR, Stein R, Ribeiro JP. Addition of inspiratory muscle training to aerobic training improves cardiorespiratory responses to exercise in patients with heart failure and inspiratory muscle weakness. *Am Heart J* 2009; **158**: 768 e1–7.
154. Wisloff U, Stoylen A, Loennechen JP, Bruvold M, Rognmo O, Haram PM, Tjonna AE, Helgerud J, Slordahl SA, Lee SJ, Videm V, Bye A, Smith GL, Najjar SM, Ellingsen O, Skjaerpe T. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study. *Circulation* 2007; **115**: 3086–3094.
155. Witham MD, Fulton RL, Greig CA, Johnston DW, Lang CC, van der Pol M, Boyers D, Struthers AD, McMurdo ME. Efficacy and cost of an exercise program for functionally impaired older patients with heart failure: a randomized controlled trial. *Circ Heart Fail* 2012; **5**: 209–216.
156. Witham MD, Gray JM, Argo IS, Johnston DW, Struthers AD, McMurdo ME. Effect of a seated exercise program to improve physical function and health status in frail patients > or = 70 years of age with heart failure. *Am J Cardiol* 2005; **95**: 1120–1124.
157. Yaylalı YT, Fındıkoğlu G, Yurtdaş M, Konukçu S, Şenol H. The effects of baseline heart rate recovery normality and exercise training protocol on heart rate recovery in patients with heart failure. *Anatol J Cardiol* 2015; **15**: 727–734.
158. Zwisler AD, Schou L, Soja AM, Bronnum-Hansen H, Gluud C, Iversen L, Sigurd B, Madsen M, Fischer-Hansen J, group D. A randomized clinical trial of hospital-based, comprehensive cardiac rehabilitation versus usual care for patients with congestive heart failure, ischemic heart disease, or high risk of ischemic heart disease (the DANREHAB trial)—design, intervention, and population. *Am Heart J* 2005; **150**: 899.
159. Chew HSJ, Sim KLD, Cao X, Chair SY. Motivation, challenges and self-regulation in heart failure self-care: a theory-driven qualitative study. *Int J Behav Med* 2019; **26**: 474–485.
160. Brodie DA, Inoue A. Motivational interviewing to promote physical activity for people with chronic heart failure. *J Adv Nurs* 2005; **50**: 518–527.
161. Knittle K, Heino M, Marques MM, Stenius M, Beattie M, Ehbrecht F, Hagger MS, Hardeman W, Hankonen N. The compendium of self-enactable techniques to change and self-manage motivation and behaviour v.1.0. *Nat Hum Behav* 2020; **4**: 215–223.
162. Dalal HM, Taylor RS, Jolly K, Davis RC, Doherty P, Miles J, van Lingen R, Warren FC, Green C, Wingham J, Greaves C, Sadler S, Hillsdon M, Abraham C, Britten N, Frost J, Singh S, Hayward C, Eyre V, Paul K, Lang CC, Smith K. The effects and costs of home-based rehabilitation for heart failure with reduced ejection fraction: the REACH-HF multicentre randomized controlled trial. *Eur J Prev Cardiol* 2019; **26**: 262–272.
163. Okwose NC, O'Brien N, Charman S, Cassidy S, Brodie D, Bailey K, MacGowan GA, Jakovljevic DG, Avery L. Overcoming barriers to engagement and adherence to a home-based physical activity intervention for patients with heart failure: a qualitative focus group study. *BMJ Open* 2020; **10**: e036382.
164. Bellg AJ, Borrelli B, Resnick B, Hecht J, Minicucci DS, Ory M, Ogedegbe G, Orwig D, Ernst D, Czajkowski S. Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. *Health Psychol* 2004; **23**: 443.
165. Horner S, Rew L, Torres R. Enhancing intervention fidelity: a means of strengthening study impact. *J Spec Pediatr Nurs* 2006; **11**: 80–89.
166. Taylor KL, Weston M, Batterham AM. Evaluating intervention fidelity: an example from a high-intensity interval training study. *PLoS ONE* 2015; **10**: e0125166.
167. Campbell KL, Neil SE, Winters-Stone KM. Review of exercise studies in breast cancer survivors: attention to principles of exercise training. *Br J Sports Med* 2012; **46**: 909–916.
168. McGregor G, Powell R, Finnegan S, Nichols S, Underwood M. Exercise rehabilitation programmes for pulmonary hypertension: a systematic review of intervention components and reporting quality. *BMJ Open Sport Exerc Med* 2018; **4**: e000400.
169. Sandercock GR, Cardoso F, Almodhy M, Pepera G. Cardiorespiratory fitness changes in patients receiving comprehensive outpatient cardiac rehabilitation in the UK: a multicentre study. *Heart* 2013; **99**: 785–790.
170. Abell B, Glasziou P, Hoffmann T. Reporting and replicating trials of exercise-based cardiac rehabilitation: do we know what the researchers actually did? *Circ Cardiovasc Qual Outcomes* 2015; **8**: 187–194.