Exercise heart rate guidelines overestimate recommended intensity for chronic heart failure patients

Louisa Beale, John Silberbauer, Guy Lloyd, Helen Carter, Jo Doust, Gary Brickley

Authors

Louisa Beale
Lecturer and BACR Phase IV Exercise Instructor

Helen Carter
Research Fellow

Jo Doust
Professor of Exercise Physiology and Head of School, and Chair of the British Association of Sport and Exercise Sciences

Gary Brickley
Senior Lecturer

Chelsea School Research Centre, University of Brighton, Denton Road, Eastbourne, BN20 7SR.

John Silberbauer
Research Registrar

Guy Lloyd
Consultant Cardiologist

Eastbourne District General Hospital, Kings Drive, Eastbourne, BN21 2UN.

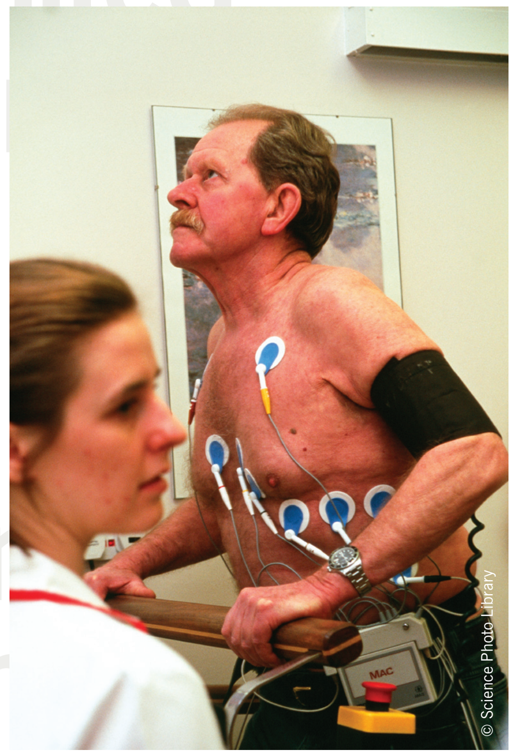
Correspondence to:
Ms L Beale
(lb33@brighton.ac.uk)

Key words

chronic heart failure, exercise training

Br J Cardiol 2010;**17**:133-7

In UK cardiac rehabilitation programmes, exercise training is often set at a percentage of maximal heart rate or heart rate reserve, either predicted or measured. Problems may arise when using this method for chronic heart failure (CHF) patients who often have chronotropic incompetence and are treated with beta blockers. A safer approach is to use cardiopulmonary exercise testing to prescribe training below the ventilatory threshold, thus ensuring that the exercise is moderate. The aim of this study was to determine whether British Association for Cardiac Rehabilitation (BACR) heart rate guidelines prescribe moderate intensity exercise for CHF patients. The only target heart rate range to prescribe exercise below the ventilatory threshold was 60–80% measured maximum heart rate. Target heart rates calculated from predicted maximum values were higher than those from measured values, and the heart rate reserve method resulted in the highest target heart rates. Cardiac rehabilitation exercise practitioners should be aware that these methods may well result in CHF patients performing heavy rather than moderate exercise.



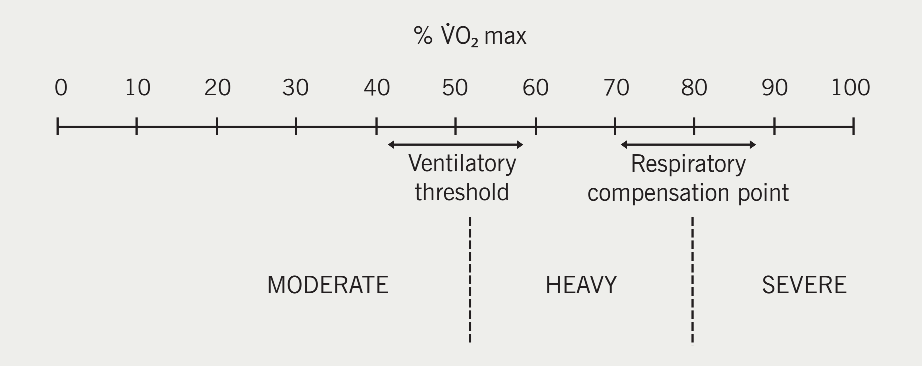
© Science Photo Library

Introduction

Exercise training is recommended for chronic heart failure (CHF) patients in New York Heart Association (NYHA) Class II and III,[1] and can be successfully incorporated into general cardiac rehabilitation programmes in the UK.[2] Prescribing exercise of an appropriate intensity can be a challenge. Guidelines for defining exercise intensity include percentages of maximum oxygen uptake ($\dot{V}O_{2max}$) or heart rate (HR_{max}), and $\dot{V}O_2$ reserve ($\dot{V}O_2R$) or heart rate reserve (HRR). However, there is considerable variability among methods of expressing exercise intensity in elderly subjects and cardiac patients, including CHF.[3-5] In addition, chronotropic incompetence is common in CHF, and the widespread use of beta blockers, which reduce resting and maximum HR, has confounded the issue further.[6]

The European Society of Cardiology recommends that cardiopulmonary exercise testing should be used to objectively evaluate functional capacity and prescribe exercise.[1] However, this is not feasible

Figure 1. Exercise intensity transitions defined by incremental cardiopulmonary exercise testing. Ventilatory threshold generally occurs at 40–60% $\dot{V}O_{2max}$, and respiratory compensation point at 70–90% $\dot{V}O_{2max}$



on many cardiac rehabilitation programmes, and although individual clinical history and symptoms are taken into account, exercise is commonly prescribed from generic HR guidelines. The British Association for Cardiac Rehabilitation (BACR) recommends target HR ranges of 60–80% predicted HR_{max} or 40–70% HRR, combined with rating of perceived exertion (RPE) of 12–15 on the Borg 6–20 scale.[7]

The thresholds that determine exercise intensity occur at a different percentage of maximal capacity in individuals,[8] hence a group of CHF patients exercising at 50% $\dot{V}O_{2max}$ may be working at different relative intensities. For that reason, intensities based solely on a percentage of HR_{max} or HRR are also likely to impose variable cardiovascular and metabolic demands in individuals,[9] including CHF patients.[10]

The ventilatory threshold marks the transition from moderate sustainable exercise to heavy exercise, and generally occurs between 40% and 60% $\dot{V}O_{2max}$. The respiratory compensation point marks the transition from heavy to severe exercise, which will quickly result in exhaustion, and generally occurs between 70% and 90% $\dot{V}O_{2max}$ (**figure 1**). There is some concern that exercising above the ventilatory threshold increases left ventricular wall stress in CHF,[11] and may induce deterioration in left ventricular function.[12] Hence, it has been suggested that an intensity at or below ventilatory threshold is appropriate for CHF.[13] It is questionable whether conventional HR guidelines are effective at prescribing exercise at this intensity, particularly in cardiac patients, including CHF.

The aim of this study was to determine whether current HR guidelines prescribe moderate intensity exercise for CHF patients.

Methods

Eighteen clinically stable CHF (NYHA Class II–III, left ventricular ejection fraction [LVEF] <40%) patients were recruited from Eastbourne District General Hospital. Patients in atrial fibrillation and those whose medication had been changed during the preceding four weeks were excluded from the study. They performed an incremental exercise test, with increments of 10 W/min until volitional exhaustion, on a cycle ergometer (Lode Corival, Groningen, The Netherlands). All patients had previously performed at least one similar exercise test to exhaustion. HR and respiratory gas exchange were recorded throughout. $\dot{V}O_{2peak}$ was expressed as the highest value from a 30 second moving average during the final stage, or within 30 seconds of completion, of the exercise test. Ventilatory threshold was identified by the V-slope method and confirmed by plots of the ventilatory equivalent and end tidal pressure for oxygen and carbon dioxide. Respiratory compensation point was determined as the point when ventilation increased disproportionately to carbon dioxide output, confirmed by plots of the ventilatory equivalent and end tidal pressure for oxygen and carbon dioxide.[8]

Target exercise training HRs were calculated according to BACR guidelines (60–80% HR_{max} and 40–70% HRR) from both measured and predicted HR_{max} values:

- HR_{max} = highest HR recorded during the incremental exercise test
- Predicted HR_{max} = 220 – age, with a further 30 beats/min deducted for patients on beta blockers, according to BACR guidelines
- HRR = HR_{max} – resting HR
- Predicted HRR = predicted HR_{max} – resting HR.

The prevalence of chronotropic incompetence, defined as <80% age-predicted maximum HR or HRR,[6] was also calculated.

Statistical analysis was performed by SPSS for Windows (v15). Paired *t*-tests were used to see if there was a difference between predicted and measured values for HR_{max} and HRR, and target HR derived from them. One-way ANOVA followed by *post hoc* tests with the Bonferroni adjustment were performed to see if there was a difference between the methods for calculating upper and lower BACR target HR ranges. Data are presented

Table 1. Patient characteristics (mean ± SD)

Age (years)	74 ± 9
Male/female	12/6
Height (cm)	172 ± 11
Body mass (kg)	86 ± 18
NYHA class II/III	13/5
Aetiology (ischaemic/dilated cardiomyopathy)	10/8
Medication:	
ACE inhibitor	13
angiotension II receptor blocker	4
beta blocker	15
anti-arrhythmic (amiodarone/digoxin)	2/2
diuretic	13
Resting heart rate (beats/min)	59 ± 8

Key: ACE = angiotensin-converting enzyme; NYHA = New York Heart Association; SD = standard deviation

Table 2. Variables measured at ventilatory threshold during the incremental exercise test

Variable	Ventilatory threshold
Work rate (W)	37 ± 2
Heart rate (beats/min)	80 ± 3
% HR_{max}	81 ± 2
% Predicted HR_{max}	71 ± 3
% HRR	57 ± 4
% Predicted HRR	44 ± 4
Average $\dot{V}O_2$ (ml/min)	820 ± 59
% $\dot{V}O_{2peak}$	67 ± 2

Key: HR = heart rate; HRR = heart rate reserve; VO_2 = oxygen uptake

as mean ± standard error of the mean (SEM) unless otherwise indicated. The level of significance was set at $p<0.05$.

Results

Patient characteristics are presented in **table 1**. $\dot{V}O_{2peak}$ was 1240 ± 100 ml/min (14.4 ± 0.88 ml/kg/min), peak work rate was 80 W, and all patients achieved a peak respiratory exchange ratio >1.0 (mean 1.12 ± 0.02, range 1.01–1.24). Details of ventilatory threshold are shown in **table 2**. Respiratory compensation point was identified in nine patients and HR was on average 10 ± 2 beats/min higher than HR at ventilatory threshold.

Predicted HR_{max} was significantly higher than measured HR_{max}, therefore, target training HR were significantly higher when calculated from predicted HR_{max} (**table 3**). There were also significant differences in the lower and upper HR targets between the $\%HR_{max}$ and %HRR methods ($p<0.01$).

Target HR ranges calculated by the different methods are illustrated in **figure 2**, which shows that the only method to prescribe exercise entirely below ventilatory threshold was 60–80% measured HR_{max}.

Table 4 shows the number of patients meeting the criteria for chronotropic incompetence.

Discussion

The aim of this study was to investigate if current exercise training HR guidelines correspond to moderate intensity exercise training for CHF patients. The only target HR range to prescribe exercise below the ventilatory threshold was 60–80% measured HR_{max}. Target HR ranges calculated from predicted maximum values were significantly higher than those calculated from measured maximum values and may result in overestimation of exercise intensity prescription in CHF. In addition, the two methods recommended by BACR did not correspond: 40–70% HRR was significantly higher than 60–80% HR_{max}.

HR_{max} measured during the exercise test was 12% lower than predicted HR_{max} after adjusting for beta-blockade. Although VO_{2peak} values are generally 10% lower in cycle compared with treadmill exercise, due to the lower exercising muscle mass, HR_{max} does not differ between exercise modes in CHF.[14] All patients achieved a maximal respiratory exchange ratio value >1.0, confirming adequate effort.[15] Nevertheless, patients may have been limited by local muscular fatigue or dyspnoea before the cardiovascular system was maximally stressed, or by chronotropic incompetence.[16] In agreement with previous findings,[6] using 80% age-predicted HRR rather than 80% age-predicted HR as a cut-off point results in more patients being identified with chronotropic incompetence, and patients taking beta blockers were more likely to meet the criteria. An arbitrary deduction of 30 beats/min without consideration of different types and doses of medication, or age and individual response, is unlikely to accurately reflect the HR-lowering effect of beta blockers. Anti-arrhythmic medication may also reduce HR,[7] but the extent of the effect remains unclear. Although beta-blockade in CHF lowers HR, it does not reduce exercise capacity,[17] or limit the benefits of exercise training in CHF.[18] Indeed, maximum HR may increase following training, hence, target HR may need to be adjusted as training progresses.[19]

Exercise training at an intensity no higher than the ventilatory threshold has been recommended, yet the upper end of BACR target HR ranges may well exceed this, thus

Table 3. Comparison of predicted (adjusted for medication effects) and measured heart rate variables (mean ± SEM)

	Predicted (beats/min)	Measured (beats/min)	Significance
Maximum heart rate	121 ± 2	106 ± 3	**
Heart rate reserve	62 ± 4	47 ± 2	**
BACR training heart rates:			
Lower limit (60% maximum heart rate)	72 ± 2	64 ± 2	**
Upper limit (80% maximum heart rate)	97 ± 2	85 ± 2	**
Lower limit (40% heart rate reserve)	84 ± 2	78 ± 2	NS
Upper limit (70% heart rate reserve)	102 ± 2	92 ± 2	*

** $p<0.01$, * $p<0.05$, NS = not significant

Key: BACR = British Association for Cardiac Rehabilitation; SEM = standard error of the mean

Table 4. Number of patients fulfilling criteria for chronotropic incompetence (peak heart rate <80% age-predicted maximum heart rate or heart rate reserve) (n=18)

	Without adjustment for beta-blockade	–30 beats/min adjustment for beta-blockade
<80% age-predicted HR_{max}	14	5
<80% age-predicted HRR	17	5

Key: HR = heart rate; HRR = heart rate reserve prescribing heavy rather than moderate exercise. Using 40–70% predicted HRR may exceed the respiratory compensation point, since HR at this threshold was only 10 beats/min higher than at ventilatory threshold. Previous studies have also demonstrated that conventional exercise prescription methods result in HR ranges above ventilatory threshold[20] and may compromise left ventricular function.[21] Despite the methodological differences in the determination of ventilatory threshold and training intensities, these studies demonstrate the variable HR response in CHF.

This study indicates that predicted HR is an unreliable exercise prescription method for CHF, and that the different BACR target HR calculation methods do not agree. Exercise practitioners should be aware that the HRR method may prescribe heavy, or even severe, intensity exercise. An incremental cardiopulmonary exercise test to determine ventilatory threshold is recommended to ensure that moderate intensity exercise is prescribed

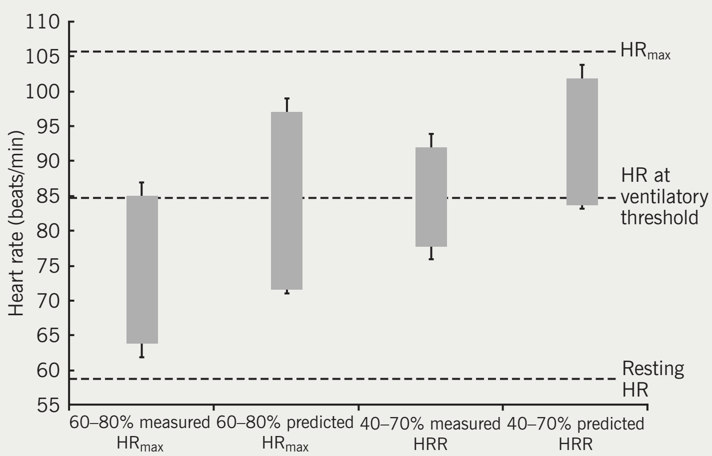
Acknowledgements

This research was supported by Eastbourne Hospital Research and Development Fund, and The Peel Medical Trust.

Conflict of interest

None declared.

Figure 2. Target heart rate ranges calculated by the different methods recommended in the British Association for Cardiac Rehabilitation (BACR) guidelines. The bars depict the target heart rate ranges (± SEM). Mean heart rate at rest, ventilatory threshold, and peak exercise are indicated by the dotted lines.



Key: HR = heart rate; HRR = heart rate reserve

Key messages

- British Association for Cardiac Rehabilitation (BACR) exercise heart rate guidelines may prescribe heavy rather than moderate exercise
- Predicted heart rate methods are unreliable due to the effects of medication and chronotropic incompetence
- Cardiopulmonary exercise testing is recommended in order to prescribe moderate intensity exercise for chronic heart failure patients

Definitions

Heart Rate Reserve (HRR)	The difference between maximum and resting heart rate (HR)
Oxygen uptake reserve ($\dot{V}O_2R$)	The difference between maximum and resting oxygen uptake
Maximum oxygen uptake ($\dot{V}O_{2max}$)	The highest oxygen uptake measured during an incremental exercise test for a specific mode of exercise
Peak oxygen uptake ($\dot{V}O_{2peak}$)	The highest oxygen uptake achieved for a presumed maximal effort
Ventilatory threshold	The transition from moderate exercise (that can be sustained indefinitely) to heavy exercise. Above this threshold, aerobic energy production is supplemented by anaerobic mechanisms. This is reflected by the onset of lactic acidosis, which stimulates the ventilatory drive. It is determined during an incremental exercise test via respiratory gas analysis as the point at which ventilation and carbon dioxide output increase disproportionately to oxygen uptake
Respiratory compensation point	The transition from heavy exercise to severe exercise. Above this threshold, lactic acid production can no longer be compensated for by circulating bicarbonate, and hyperventilation begins. It is detected during an incremental exercise test via respiratory gas analysis as the point at which ventilation increases disproportionately to carbon dioxide output

References

1. Giannuzzi P, Tavazzi L, Meyer K *et al.* Recommendations for exercise training in chronic heart failure patients. Working Group on Cardiac Rehabilitation & Exercise Physiology and Working Group on Heart Failure of the European Society of Cardiology. *Eur Heart J* 2001;**22**:125–35.

2. Austin J, Williams R, Ross L *et al.* Randomised controlled trial of cardiac rehabilitation in elderly patients with heart failure. *Eur J Heart Failure* 2005;**7**:411.

3. Panton L, Graves J, Pollock M *et al.* Relative heart rate, heart rate reserve, and VO2 during submaximal exercise in the elderly. *J Gerontol A Biol Sci Med Sci* 1996;**51**:M165–M171.

4. Brawner CA, Keteyian SJ, Ehrman JK. The relationship of heart rate reserve to VO2 reserve in patients with heart disease. *Med Sci Sports Exerc* 2002;**34**:418–22.

5. Mezzani A, Corra U, Giordano A *et al.* Unreliability of the %VO2 reserve versus %heart rate reserve relationship for aerobic effort relative intensity assessment in chronic heart failure patients on or off beta-blocking therapy. *Eur J Cardiovasc Prev Rehabil* 2007;**14**:92–8.

6. Witte KKA, Cleland JGF, Clark AL. Chronic heart failure, chronotropic incompetence, and the effects of beta blockade. *Heart* 2006;**92**:481–6.

7. British Association for Cardiac Rehabilitation. *BACR phase IV instructor training module*. 4th edition, Leeds: Human Genetics Europe, 2006.

8. Wasserman K, Hansen JE, Sue DY *et al.* Principles of exercise testing and interpretation including pathophysiology and clinical applications, 4th edition. Philadelphia: Lippincott Williams and Williams, 2005.

9. Dwyer J. Metabolic character of exercise at traditional training intensities in cardiac patients and healthy persons. *J Cardiopulmonary Rehabil* 1994;**14**:189–96.

10. Coplan NL, Gleim GW, Nicholas JA. Using exercise respiratory measurements to compare methods of exercise prescription. *Am J Cardiol* 1986;**58**:832.

11. Demopoulos MDL, Bijou MDR, Fergus MDI *et al.* Exercise training in patients with severe congestive heart failure: enhancing peak aerobic capacity while minimizing the increase in ventricular wall stress. *J Am Coll Cardiol* 1997;**29**:597.

12. Koike A, Itoh H, Taniguchi K *et al.* Detecting abnormalities in left ventricular function during exercise by respiratory measurement. *Circulation* 1989;**80**:1737–46.

13. Meyer T, Gorge G, Schwaab B *et al.* An alternative approach for exercise prescription and efficacy testing in patients with chronic heart failure: a randomized controlled training study. *Am Heart J* 2005;**149**:926.

14. Page E, Cohen-Solal A, Jondeau G *et al.* Comparison of treadmill and bicycle exercise in patients with chronic heart failure. *Chest* 1994;**106**:1002–06.

15. Ingle L. Theoretical rationale and practical recommendations for cardiopulmonary exercise testing in patients with chronic heart failure. *Heart Failure Rev* 2007;**12**:12–22.

16. Vallebona A, Gigli G, Orlandi S *et al.* Heart rate response to graded exercise correlates with aerobic and ventilatory capacity in patients with heart failure. *Clin Cardiol* 2005;**28**:25–9.

17. Witte KKA, Thackray S, Clark NP *et al.* The effects of long-term beta-blockade on the ventilatory responses to exercise in chronic heart failure. *Eur J Heart Failure* 2005;**7**:612.

18. Forissier JF, Vernochet P, Bertrand P *et al.* Influence of carvedilol on the benefits of physical training in patients with moderate chronic heart failure. *Eur J Heart Failure* 2001;**3**:335.

19. Keteyian SJ, Brawner CA, Schairer JR *et al.* Effects of exercise training on chronotropic incompetence in patients with heart failure. *Am Heart J* 1999;**138**:233.

20. Strzelczyk TA, Quigg RJ, Pfeifer PB *et al.* Accuracy of estimating exercise prescription intensity in patients with left ventricular systolic dysfunction. *J Cardiopulmonary Rehabil* 2001;**21**:158–63.

21. Normandin EA, Camaione D, Clark B *et al.* A comparison of conventional versus anaerobic threshold exercise prescription methods in subjects with left ventricular dysfunction. *J Cardiopulmonary Rehabil* 1993;**13**:110–16.

Diary

2010

1st–5th June	National Thrombosis Week 'Spot the Clots' email: lifeblood.charity@googlemail.com website: www.thrombosis-charity.org.uk
7th–9th June	British Cardiovascular Society Annual Scientific Conference 2010, Manchester website: www.bcs.com
18th–21st June	European Society of Hypertension 2010 Annual Scientific Meeting, Oslo, Norway website: www.ehsonline.org/Meetings/AnnualMeeting.aspx
20th–23rd June	78th European Atherosclerosis Society Congress, Hamburg, Germany website: www2.kenes.com/eas2010/pages/home.aspx
7th–9th July	HEART UK 25th Annual Conference in association with SHARP, Edinburgh website: www.heartuk.org.uk
26th–27th July	Echocardiography in Practice 2010, London email: health.enquiries@canterbury.ac.uk
28th July	Advances in Cardiology 2010, London email: health.enquiries@canterbury.ac.uk
28th August–1st September	European Society of Cardiology (ESC) 2010, Stockholm, Sweden website: www.escardio.org
20th–24th September	46th European Association for the Study of Diabetes Annual Meeting, Stockholm, Sweden website: www.easd.org
21st–25th September	Transcatheter Therapeutics 2010, Washington DC, USA web: www.tctconference.com
29th September–1st October	13th Primary Care Cardiovascular Society Annual General Meeting 'Cardiovascular Disease – the next 10 years', Leeds website: www.pccs.org.uk email: office@pccs.org
7th–8th October	British Association for Cardiac Rehabilitation Annual Conference 2010, Liverpool website: www.bcs.com/bacr email: bacr@bcs.com
13th–17th November	American Heart Association Scientific Sessions 2010, Chicago, USA website: www.scientificsessions.americanheart.org