



Tang, L. H., Zwisler, A.-D., Berg, S. K., Doherty, P., Taylor, R. S. and Langberg, H. (2017) Is the cardiovascular response equivalent between a supervised center-based setting and a self-care home-based setting when rating of perceived exertion is used to guide aerobic exercise intensity during a cardiac rehabilitation program? *American Journal of Physical Medicine and Rehabilitation*, 96(6), pp. 381-387.
(doi: [10.1097/PHM.0000000000000628](https://doi.org/10.1097/PHM.0000000000000628)).

This is the author's final accepted version.

There may be differences between this version and the published version. You are advised to consult the publisher's version if you wish to cite from it.

<http://eprints.gla.ac.uk/201123/>

Deposited on: 18 October 2019

Enlighten – Research publications by members of the University of Glasgow
<http://eprints.gla.ac.uk>

Is the Cardiovascular Response Equivalent Between a Supervised Center-Based Setting and a Self-care Home-Based Setting When Rating of Perceived Exertion Is Used to Guide Aerobic Exercise Intensity During a Cardiac Rehabilitation Program?

Lars H. Tang, MSc, Ann-Dorthe Zwisler, PhD, Selina K. Berg, PhD, Patrick Doherty, PhD, Rod S. Taylor, PhD, and Henning Langberg, PhD, DMSc

Objectives: The aim of this study was to investigate if exercise intensity guided by rating of perceived exertion (RPE) results in an equivalent cardiovascular response when applied in either a center-based or a home-based setting.

Design: Data from patients with heart disease (post-valve surgery and atrial fibrillation post-radiofrequency ablation) participating in exercise-based rehabilitation were included. Patients performed a 12-week program in either a center- or a home-based setting. Using RPE, patients recorded their exercise intensity 3 times during an aerobic training phase. Exercise intensity was objectively measured using heart rate (HR) monitors.

Results: A total of 2622 RPE values with corresponding HR data were available. There was no difference in the level of association (interaction $P = 0.51$) between HR and RPE seen in the center-based setting (mean of 6.1 beats/min per 1.0 difference in RPE; 95% confidence interval, 4.8–7.5 beats/min) compared with the home-based setting (mean of 5.3 beats/min per 1.0 difference in RPE; 95% confidence interval, 4.0–6.5 beats/min). The level of patient familiarization, exercise intensity, and patient characteristics did not affect the level of association between RPE and HR.

Conclusions: Independent of exercise setting, RPE appears to be equally effective in guiding exercise intensity of patients participating in cardiac rehabilitation.

Key Words: Atrial Fibrillation, Exercise Prescription, Exercise Setting, Exercise Therapy, Heart Rate, Heart Valve Diseases

(*Am J Phys Med Rehabil* 2016;00: 00–00)

Cardiac rehabilitation (CR) has been shown to have beneficial health effects for patients living with heart disease.^{1–3} Unfortunately, fewer than half of eligible patients are currently participating in CR in most European countries.⁴ Cardiac rehabilitation programs have traditionally been delivered in a supervised center setting, typically at a local hospital,⁴ but because of the current problem of poor uptake, alternative CR delivery models have been developed, including the delivery of CR in a nonsupervised home-based setting.^{5,6}

A core component of CR is exercise training. Adequate exercise intensity is a key consideration as it is closely associated with the level of improvement in exercise capacity and associated reduction in future cardiac events.^{7,8} Exercise intensity is often estimated using objective measurements such as oxygen uptake or heart rate (HR). Nevertheless, oxygen uptake is complex to assess and is not available across all exercise settings, and HR can be difficult to apply in some cardiac patients because of reasons such as arrhythmia or the use of β -blockers.⁷

Rating of perceived exertion (RPE)⁹ is a subjective assessment method that is widely accepted for guiding exercise intensity and recommended in current guidelines for exercise-based CR.^{8,10} The simplicity of RPE makes it an ideal tool to use in routine practice across settings.

Rating of perceived exertion has been shown to be a reliable and valid method for monitoring exercise intensity in healthy adults.^{11,12} In populations with heart disease, RPE has been demonstrated to have good reliability¹³ but may overestimate or underestimate exercise intensity.^{14,15} A number of studies have shown that such patients can regulate exercise intensity by discrimination between RPE values.^{15–17} Nevertheless, RPE has not previously been investigated in a real life setting as these previous studies have been conducted in an experimental or laboratory design. Considerable caution is therefore needed in their generalizability to everyday clinical practice. We have recently shown that cardiac patients can use RPE to alter their cardiac response in everyday clinical practice

From the Department of Cardiology, The Heart Centre, Rigshospitalet, Copenhagen University Hospital (LHT, SKB); CopenRehab, Section of Social Medicine, Department of Public Health, University of Copenhagen (LHT, HL); Department of Physiotherapy and Occupational Therapy, Faculty of Health and Technology, Metropolitan University College, Copenhagen (LHT); National Centre for Rehabilitation and Palliative Care, University of Southern Denmark and Odense University Hospital, Odense (ADZ), Denmark; Department of Health Sciences, University of York, York (PD); and Institute of Health Research, University of Exeter Medical School, Exeter, England (RST).

All correspondence and requests for reprints should be addressed to: Lars H. Tang, MSc, The Heart Centre, Rigshospitalet, Blegdamsvej 9, 2100 Copenhagen, Denmark. Financial support was given by the Danish Council for Strategic Research (no. 10-092790), Faculty of Health and Technology at Metropolitan University

College, The Research Committee at the Heart Centre at Rigshospitalet and the Association of Danish Physiotherapists. All funding was provided as nonrestricted research grants, and funders have no influence on the trial design, the execution of the trial, or the interpretation of the data.

The manuscript contains original unpublished material and has never been presented elsewhere.

Financial disclosure statements have been obtained, and no conflicts of interest have been reported by the authors or by any individuals in control of the content of this article.

Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.

ISSN: 0894-9115

DOI: 10.1097/PHM.0000000000000628

regardless whether they are taking HR-reducing medications or not.¹⁸ However, our analysis did not take the use of different exercise setting into account.

In a supervised center-based setting, patients typically receive guidance on their exercise intensity from health care professionals, whereas in self-care home-based setting, regulation of exercise intensity depends on the patients' own abilities. Evidence has shown that supervised exercise sessions can be superior to nonsupervised sessions in achieving beneficial health effects,¹⁹ and home-based exercise programs without a structured exercise component have failed to demonstrate any clinical benefits.^{20,21} It has therefore been argued that heart disease patients may lack the ability to follow individualized exercise prescription when in a nonsupervised setting.²⁰ Given the importance of alternative delivery methods, including unsupervised home-based programs to increase the uptake in CR,^{5,6} simple methods for patients to prescribe exercise intensity are needed. Thus, we require evidence for the usability of RPE across CR settings. Because RPE is both a mental and physical tool, a number of determinants may influence its use including levels of patient anxiety or depression and characteristics such as age and gender.^{22,23} Such determinants must be explored before RPE is applied in a routine CR setting.

The primary aim of this study was to investigate if the cardiovascular response of patients with heart disease using RPE to guide exercise intensity is equivalent in a supervised center-based setting to a self-care home-based setting. We hypothesize that the cardiovascular response (defined as the slope between changes in HR (in beats/min) per 1.0-unit change in RPE) between settings is higher in patients exercising in a supervised center-based setting compared with patients in a self-care home-based setting. We also sought to examine how different exercise intensities, patient characteristics (e.g., age and gender), and psychological status might affect the cardiovascular response when using RPE in routine CR.

METHODS

This study uses data from all patients who participated in a similar exercise intervention in 2 randomized controlled trials described in full elsewhere.^{24,25} In brief, these trials investigated the effect of CR in patients with heart disease randomized to either physical exercise and psychoeducative intervention or to the usual care without supervised physical exercise training. Patients had undergone either heart valve surgery or treatment of atrial fibrillation by radiofrequency ablation, were 18 years or older, were without comorbidities complicating physical activity, and were able to speak and understand Danish. All eligible patients were informed about the trials both verbally and in writing. Written informed consent was obtained. The Regional Ethical Committee (j.nr. H-1-2011-135, j.nr. H-1-2011-157) and the Data Protection Agency (j.nr. 2007-58-0015) approved both trials.

The Exercise Intervention

In both trials, the intervention was initiated 1 month after hospital discharge and consisted of a 12-week progressive exercise program of 3 sessions per week each for approximately 60 minutes. All patients were introduced to the exercise program and undertook their first training session at a tertiary

center hospital (Department of Cardiology). Based on their own preference, each patient could then self-select to continue their exercise program either (1) in a supervised center-based setting—the original tertiary hospital center or at 1 of 29 collaborating training locations that included local hospitals or health centers in a municipality where personnel were available and instructed in delivering the exercise training intervention, or (2) in a self-care home-based setting, where patients had access to a stationary bike at home or in a local training facility and where no supervision was provided. All patients underwent a maximum cardiopulmonary exercise test before the exercise intervention.^{24,25}

Data Collection and Management

The aerobic exercise intervention was divided into a 10-minute warm-up phase followed by a 20-minute primary aerobic exercise phase performed on a stationary cycle. The 20-minute aerobic exercise phase was subdivided into 3 incremental exercise steps, which varied in duration and intensity. The duration was always shortest in the first and third exercise step (between 2 and 5 minutes) and longest in the second step (between 10 and 15 minutes). Exercise intensity was prescribed using the 15-point Borg scale⁹ and progressed throughout the exercise intervention with the first and third exercise step reaching from RPE 11 to 14 and the second exercise step from RPE 13 to 17 during the 12 weeks of training. Patients were instructed to perform their aerobic training at an intensity corresponding to the preselected RPE value, if they were able. If not, they should perform the exercise session at the highest intensity they deemed as possible. For safety reasons, patients were strictly informed not to exceed the preselected RPE values. After each single training session, patients were asked to note their exact RPE values, which were then used in the analysis.

To objectively assess the cardiovascular response, HR was measured during all exercise sessions with either Polar HR RS 400 monitors (Polar Electro, Kempele, Finland) or T-shirts with wireless integrated electrocardiographic electrodes (CorusFit Cardio and Corus Exercise Assistant, version 2.0.16; CorusFit Inc, Jyväskylä, Finland). We were unable to blind the patients in the home-based setting to their HR monitors. However, we encouraged these patients not to focus on their HR monitor during the aerobic training session, and they were not provided with specific instructions on how to monitor the training intensity based on HR or how RPE corresponds with HR.

After the intervention period, data from the diaries on sessions 1 to 6, 10 to 12, 16 to 18, 22 to 24, and 31 to 33 were analyzed, because these sessions had incremental steps of similar time duration and the longest duration in the first and third steps (5-10-5 minutes), which enabled patients to reach a steady-state period in exercise intensity. Thus, a maximum of 18 sessions was available for each patient.

The date of training was used to link HR with their reported RPE data. An exercise session was excluded if either the RPE or HR data were missing for a training session. Additional HR recordings were excluded if irregular frequency changes with sudden repeated alterations exceeding 10 beats/min or more were observed. To avoid systematic bias in the selection process, data from all exercise sessions were examined

by 2 independent investigators. Inconsistencies between investigators were reviewed, and a third investigator was used in cases where consensus could not be reached.

The cardiovascular response was defined as the slope between changes in HR (in beats/min) per 1.0-unit change in RPE and expressed to a given RPE value, by calculating an average HR in a window from the last 2 minutes for each exercise step in accordance with Aamot et al.¹⁵ (For an illustration, see Tang et al.¹⁸) All analyses combined the data from the 3 exercise steps and were adjusted for whether patients were taking HR-reducing medications (β -blockers and calcium antagonists) or not. Adjusting for rate-reducing medication slightly improved the strength of the association between HR and RPE (~9%).¹⁸

Patient demographic information was collected at baseline together with anxiety and depression scores using the Hospital Anxiety and Depression Scale (HADS). Disease-specific symptoms were assessed using the New York Heart Association (NYHA) Functional Classification for patients who had undergone heart valve surgery and the European Heart Rhythm Association (EHRA) score of atrial fibrillation-related symptoms in patients treated for atrial fibrillation.

To explore if patients needed a familiarization period before knowing RPE, we divided the exercise sessions performed

by a patient during the 12-week training period into 2 groups; 1 group contained all exercise sessions within the first 2 weeks of training, and the other group, the rest (>2 weeks). To test the influence of exercise intensity when using RPE, we divided exercise intensity into low/moderate (RPE ≤ 15) and high intensity (RPE >15) as RPE is found to be underestimated at higher ranges.²⁶

Statistical Analysis

Statistical analyses were performed using the software SAS Enterprise Guide 5.1 (SAS Institute Inc., Cary, North Carolina). An independent 2-sample *t* test, Wilcoxon-Mann-Whitney test, or a χ^2 test was used to examine the difference in HR, RPE, the number of training sessions per patient, and demographic variables between center- and home-based settings. Linear regression was used to assess the association between RPE and HR in comparison to setting. Regression was also used to explore whether familiarization with RPE, the range of exercise intensities, patient characteristics (i.e., age and gender), or psychological status (anxiety and depression) could influence the use of RPE. The interaction between each of these variables and RPE was determined in order to explore whether there are significant differences in the cardiovascular responses. To increase the statistical power, we kept the

TABLE 1. Baseline characteristics, training location, cardiac history, medical records, and conditions presented for all patients and for patients in each of the 2 settings

Demographic Data	All Patients (n = 97)		Center Based (n = 53)		Home Based (n = 44)		Deference Between Settings <i>P</i>
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	
Age	97	60.2 (9.6) y	53	61.5 (10.2) y	44	59.6 (8.8) y	0.334
Height	97	178.6 (9.0) cm	53	177.9 (8.7) cm	44	179.4 (9.6) cm	0.408
Weight	97	83.7 (16.5) kg	53	81.8 (16.6) kg	44	86.0 (16.2) kg	0.509
BMI	97	26.1 (4.1) kg/m ²	53	25.8 (4.5) kg/m ²	44	26.4 (3.7) kg/m ²	0.323
Sex (men/women)	71/26		40/13		31/13		0.579
Patient type (radiofrequency ablation/valve replacement)	58/39		28/25		30/14		0.125
Physical Capacity							
Watts (maximum)	95	156.8 (57.6)	52	143.9 (48.4)	43	172.4 (64.3)	0.016
Peak VO ₂ , mL/kg per min	95	23.8 (8.1)	52	22.8 (7.4)	43	25.0 (8.9)	0.189
		%		%		%	
NYHA/EHRA ^a							
I-II	74	76	44	83	30	68	0.087
III-IV	23	24	9	17	14	32	
Medical Record							
β -Blockers	34	35	19	36	15	34	0.857
Calcium antagonists	13	13	7	13	6	14	0.951
Warfarin	85	88	45	85	40	91	0.371
HADS							
Anxiety							
<8	69	71	37	70	32	73	0.752
≥ 8	28	29	16	30	16	27	
Depression							
<8	89	92	48	91	41	93	0.725 ^b
≥ 8	8	8	5	9	3	7	

^aThe NYHA Functional Classification/EHRA score of atrial fibrillation-related symptoms.

^bFisher exact test.

variables age, EHRA/NYHA, and HADS as continuous values. However, for the purposes of the presentation of data, RPE results are expressed above and below a categorical cutoff point in each variable. All models took into account the repeated-measures (clustering within subject) nature of the data. The threshold of statistical significance was taken as a $P < 0.05$.

RESULTS

Patient participation and exclusion have been described in detail elsewhere.¹⁸ In brief, RPE and HR data were available from 874 training sessions in 97 patients. As RPE was rated 3 times in each session, 2622 RPE values with corresponding HR were available for analysis.

Patients had a mean age of 60 (SD, 10) years, 71 (73 %) were men, and 39 (40%) had undergone heart valve surgery (Table 1). Fifty-three patients preferred a supervised center-based setting (1401 data points from 467 training sessions), and 44 preferred a home-based setting (1221 data points from 407 training sessions). The median number of training session available per patient was 10 (interquartile range [IQR], 4–10) with no difference between settings ($P = 0.692$). Patients in the home-based setting had a higher maximum watt level than did patients in the center-based setting (mean difference, 28.5; 95% confidence interval [CI], 5.6–51.5; $P = 0.016$). No other differences were found between settings.

RPE and HR Between Settings

Overall, the mean HR was 117 (SD, 22) beats/min, and the median RPE rating was 14 (IQR, 12–15). There was a difference in the mean HR ($P = 0.004$) and median of RPE points ($P < 0.001$) between the 2 settings, with highest values found in the supervised center-based setting with a

mean of 118 beats/min (95% CI, 117–119 beats/min) versus 115 beats/min (95% CI, 114–117 beats/min) and a median RPE of 14 (IQR, 13–15) versus median of 13 (IQR, 12–14) in the home-based setting.

Linear regression showed a similar change in HR of 6.1 beats/min (95% CI, 4.8–7.5 beats/min) and 5.3 beats/min (95% CI, 4.0–6.5 beats/min) per 1.0-unit change in RPE in a center setting and in a home-based setting, respectively. There was no evidence of an interaction in the association between HR and RPE between settings ($P = 0.510$) (Fig. 1 and Table 2).

Factors Influencing the Association Between RPE and HR

There was interaction between disease-specific symptoms measured by NYHA/ERHA and the use of RPE ($P = 0.002$). However, the difference in the association between RPE and HR within NYHA/ERHA class was small, that is, 5.6 beats/min (95% CI, 4.6–6.6 beats/min) versus 4.8 beats/min (95% CI, 3.1–6.4 beats/min) per 1.0-unit change in RPE in class I–II versus class III–IV, respectively. When excluding the 2 patients classed as class IV in a sensitivity analysis, the interaction between NYHA/ERHA and the use of RPE was no longer significant ($P = 0.371$). Higher exercise intensities (i.e., >15 RPE) tended to induce higher cardiac responses ($P = 0.096$), that is, 5.5 beats/min (95% CI, 4.5–6.5 beats/min) for RPE of 15 or less versus 8.3 beats/min (95% CI, 4.5–12.0) for RPE of greater than 15 per 1.0-unit change in RPE. A sensitivity analysis excluding the 2 class IV patients showed no change in this result ($P = 0.090$). There was no evidence of significant interactions with RPE and patient characteristics (i.e., cardiac diagnosis, age, and gender), psychological status (HADS anxiety and depression), or familiarization with RPE (Table 2). We adjusted all linear regression analyses for the observed baseline

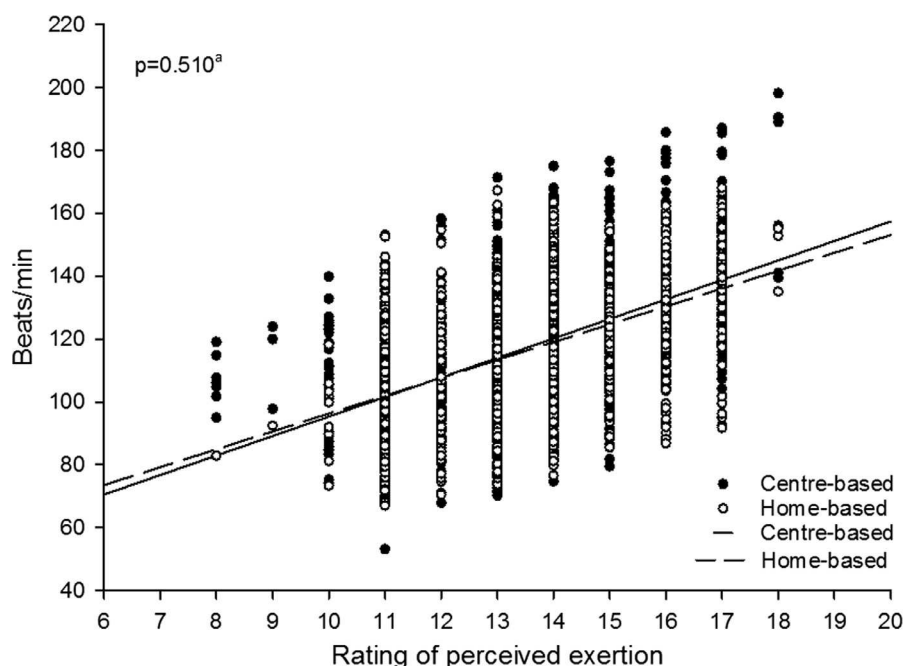


FIGURE 1. The relationship between RPE and HR in the center-based setting and home-based setting. ^aTest for interaction between settings.

TABLE 2. Summary of the linear regression relationship between HR and RPE across setting, patient characteristics, and exercise training categories

Variables	No. of Patients	No. of RPE and HR Pairs	Mean Change in HR (beats/min) per 1 Unit Change in RPE	95% Confidence Interval	Interaction (<i>P</i>)
Setting					
Supervised center-based	53	1401	6.1	4.6 to 7.5	0.510
Self-care home based	44	1221	5.3	4.0 to 6.5	
Age					
≤60 y	42	1293	5.8	4.5 to 7.1	0.647 ^b
>60 y	55	1329	5.5	4.3 to 6.7	
Sex					
Women	26	768	5.7	4.2 to 7.3	0.675
Men	71	1854	5.9	4.8 to 7.0	
Patient type					
Radiofrequency ablation	58	1488	5.2	4.3 to 6.2	0.392
Valve replacement	39	1134	6.0	4.6 to 7.4	
EHRA/NYHA ^c					
I–II	74	2013	5.6	4.6 to 6.6	0.002 ^b
III–IV	23	609	4.8	3.1 to 6.4	
HADS anxiety					
<8	69	2007	5.6	4.5 to 6.8	0.480 ^b
≥8	28	615	5.1	3.7 to 6.6	
HADS depression					
<8	89	2475	5.5	4.6 to 6.4	0.330 ^b
≥8	8	147	4.5	0.8 to 8.3	
Time of rating ^d					
≤2 wk	—	1071	6.2	4.8 to 7.6	0.155
>2 wk	—	1551	5.4	4.4 to 6.5	
RPE point					
≤15	—	2235	5.5	4.5 to 6.5	0.096
>15	—	387	8.3	4.5 to 12.0	

^aAll associations adjusted for use of HR-reducing medication.

^bBased on interaction of variable expressed as a continuous variable.

^cThe NYHA Functional Classification/EHRA score of atrial fibrillation–related symptoms.

^dRPE ratings divided into the first 2 weeks and after the first 2 weeks of the 12-week intervention period.

difference in the maximum watt level. However, it did not affect the interpretation of the findings.

DISCUSSION

Rating of perceived exertion is widely used by patients participating in exercise-based CR programs to prescribe and to guide their exercise intensity. However, there is little evidence of the ability of patients with heart disease to guide and regulate intensity using RPE in different settings. The primary aim of this study was to investigate if the cardiovascular response of patients with heart disease when using RPE to guide exercise intensity was equivalent across supervised center-based and unsupervised home-based settings. Based on 2622 pairs of RPE ratings and HR recordings, we found higher RPE and HR values when patients trained in center-based setting compared with those who trained in self-care home-based setting. However, there were no systematic differences in the association between HR and RPE across settings, indicating that RPE was equally able to guide cardiac response.

While RPE has been demonstrated to have good reliability,¹³ it is not the criterion standard to assess exercise intensity in cardiac populations, because it may overestimate or underestimate exercise intensity.^{14,15} Nonetheless, as objective assessment methods of oxygen uptake and HR are difficult to apply in everyday clinical practice (and are not applicable to patients with arrhythmias or on β -blocker medication), many CR guidelines recommend the use of RPE for assessing exercise intensity.^{8,10} These CR guidelines assume RPE to be applicable in both the center- and home-based settings. However, from a clinical perspective, there are many important differences between these 2 settings. In a supervised center-based program, health care professionals can encourage and help patients to change their exercise intensity. In contrast, in a self-care home-based program, patients perform unsupervised exercise and therefore self-manage their exercise intensity. However, this study shows that patients are equally able to use RPE to guide their cardiac response in both settings.

Somewhat higher levels of exercise intensity were seen in the supervised center-based setting compared with the self-care

home-based setting. Although higher exercise intensities have been associated with a larger increase in postrehabilitation exercise capacity,²⁷ it is important to emphasize that the difference in intensity seen in this study was very small (i.e., mean difference of 2.4 beats/min [95% CI, 0.8–4.1]). To ensure higher RPE ratings were not affecting the interaction between settings, we undertook a sensitivity analysis adjusting for higher intensity ranges (>15 RPE). This made no changes to the previous conclusion (center-based setting: 5.8 beats/min per 1.0 unit of RPE change [95% CI, 4.2–7.5 beats/min]; home-based: 5.2 beats/min per 1.0 unit of RPE change [95% CI, 3.9–6.6 beats/min]; interaction $P = 0.520$).

Our findings indicate that RPE not only can be used to guide cardiovascular response across settings but also may be applicable across a number of other factors including patient age, sex, cardiac diagnoses, level of exercise intensity, and degree of familiarization with RPE. However, further data are needed to support these other applications of RPE. Previous studies in healthy individuals have also shown that age and sex have no influence on the use of RPE.¹¹ While levels of anxiety or depression are thought to impact the use of RPE,²² this was not supported by our findings. However, our results are likely to be affected by a low occurrence of anxiety or depression in our population. A score greater than 7 is the normal threshold score when using the HADS questionnaire and defines a potential depression or anxiety. A more definite depression or anxiety score is defined by a score greater than 10, which were reported in only a few patients in the current study (anxiety [10%] and depression [2%]).²⁸ We did see some evidence of difference in the HR-RPE association due to disease severity (i.e., a mean of 5.6 beats/min [95% CI, 4.6–6.6 beats/min] per 1.0-unit change in RPE for NYHA/ERHA class I–II vs. 4.8 beats/min [95% CI, 3.1–6.4 beats/min] per 1.0-unit change in RPE for NYHA/ERHA class II–IV; interaction $P = 0.002$). That this difference in RPE-HR response was no longer apparent when we excluded patients with more severe condition (class IV) suggests that it is the higher levels of disease severity that particularly may affect the use for RPE. Nevertheless, because it has been suggested that a change in HR needs to be at least 5 beats/min to be clinically important, it could also be argued that this observed difference in HR-RPE response is unlikely to have any clinical relevance.¹⁶ Overall, our results indicate that teaching patients RPE may empower them to guide exercise intensity by themselves without other variables having a substantial clinical impact.

Strength and Limitations

The main strength of this study is the large number of exercise sessions in which we were able to assess both RPE and HR. Although these data are collected in 2 randomized trials, the rehabilitation programs in these trials^{24,25} reflect standard clinical rehabilitation provision and are reflective of real-world clinical practice. Our study does have some limitations. First, our data are limited to patients who have undergone either heart valve surgery or treatment for atrial fibrillation as diverse pathologies between cardiac diagnoses are likely to reduce the generalization of our findings to all cardiac diagnoses. Second, we used interaction analyses to examine how the HR-RPE association was affected by setting and other factors.

It has been estimated that the sample size required to detect an interaction effect is at least 4 times higher than required for a main effect of the same magnitude.²⁹ Therefore, we can only claim in this study to be able to detect relatively large differences. Nevertheless, that the mean observed interaction effects on HR were smaller than 5 beats/min is strongly suggestive that they are not clinically relevant.¹⁶ Finally, all exercise sessions were performed on stationary bike. Given that previous studies have shown RPE to be affected by exercise modality,³⁰ we need to be cautious in extrapolating our results to other forms of exercise training such as brisk walking or running.

CONCLUSIONS

This study shows that in selected heart disease patients an equivalent cardiovascular response is produced when using RPE in CR to guide exercise intensity in both supervised center-based and self-care home-based rehabilitation settings. The level of patient familiarization, exercise intensity, and patient characteristics (age, gender, cardiac diagnosis) and psychological status do not appear to influence the association between RPE and HR.

ACKNOWLEDGMENT

The authors thank everyone who participated. They especially thank the participating patients. Furthermore, they thank the physiotherapists Helena Tjalk-Bøggild, Signe Gils, Graziella Zangger, and Katrine Thingholm Erhardsen for introducing all patients to the exercise intervention. A special thanks to Merja Perhonen and Juhani Perhonen (CorusFit Inc, Jyväskylä, Finland) for developing the training diary and cooperating on the CopenHeart protocols and safety procedures.

REFERENCES

- Anderson L, Thompson DR, Oldridge N, et al: Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database Syst Rev* 2016;CD0101800
- Taylor RS, Sagar VA, Davies EJ, et al: Exercise-based rehabilitation for heart failure. *Cochrane Database Syst Rev* 2014;CD003331
- Sibiliz KL, Berg SK, Tang LH, et al: Exercise-based cardiac rehabilitation for adults after heart valve surgery. *Cochrane Database Syst Rev* 2016;CD010876
- Bjarnason-Wehrens B, McGee H, Zwisler AD, et al: Cardiac rehabilitation in Europe: results from the European Cardiac Rehabilitation Inventory Survey. *Eur J Cardiovasc Prev Rehabil* 2010;17:410–8
- Jelinek MV, Thompson DR, Ski C, et al: 40 years of cardiac rehabilitation and secondary prevention in post-cardiac ischaemic patients. Are we still in the wilderness? *Int J Cardiol* 2015;179:153–9
- Clark RA, Conway A, Poulsen V, et al: Alternative models of cardiac rehabilitation: a systematic review. *Eur J Prev Cardiol* 2015;22:35–74
- Mezzani A, Hamm LF, Jones AM, et al: Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: a joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation. *Eur J Prev Cardiol* 2013;20:442–67
- Piepoli MF, Corrà U, Carré F, et al: Secondary prevention through cardiac rehabilitation: physical activity counselling and exercise training: key components of the position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation. *Eur Heart J* 2010;31:1967–74
- Borg GA: Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982;14:377–81
- The Danish National Board of Health: *National Clinical Guidelines for Cardiac Rehabilitation [National Klinisk Retningslinje for Hjerterehabilitering]*. Copenhagen, The Danish National Board of Health, 2013
- Scherr J, Wolfarth B, Christle JW, et al: Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol* 2013;113:147–55
- Dunbar CC, Robertson RJ, Baun R, et al: The validity of regulating exercise intensity by ratings of perceived exertion. *Med Sci Sports Exerc* 1992;24:94–9

13. Buckley JP, Sim J, Eston RG: Reproducibility of ratings of perceived exertion soon after myocardial infarction: responses in the stress-testing clinic and the rehabilitation gymnasium. *Ergonomics* 2009;52:421–7
14. Whaley MH, Brubaker PH, Kaminsky LA, et al: Validity of rating of perceived exertion during graded exercise testing in apparently healthy adults and cardiac patients. *J Cardiopulm Rehabil* 1997;17:261–7
15. Aamot IL, Forbord SH, Karlsen T, et al: Does rating of perceived exertion result in target exercise intensity during interval training in cardiac rehabilitation? A study of the Borg scale versus a heart rate monitor. *J Sci Med Sport* 2014;17:541–5
16. Weiser PC, Wojciechowicz V, Funck A, et al: Perceived effort step-up procedure for self-regulating stationary cycle exercise intensity by patients with cardiovascular disease. *Percept Mot Skills* 2007;104:236–53
17. Borg G, Linderholm H: Exercise performance and perceived exertion in patients with coronary insufficiency, arterial hypertension and vasoregulatory asthenia. *Acta Med Scand* 1970;187:17–26
18. Tang LH, Zwisler AD, Taylor RS, et al: Self-rating level of perceived exertion for guiding exercise intensity during a 12-week cardiac rehabilitation programme and the influence of heart rate reducing medication. *J Sci Med Sport* 2016;19:611–5
19. Coll-Fernández R, Coll R, Muñoz-Torrero JF, et al: Supervised versus non-supervised exercise in patients with recent myocardial infarction: a propensity analysis. *Eur J Prev Cardiol* 2016;23:245–52
20. Jolly K, Taylor RS, Lip GY, et al: A randomized trial of the addition of home-based exercise to specialist heart failure nurse care: the Birmingham Rehabilitation Uptake Maximisation study for patients with Congestive Heart Failure (BRUM-CHF) study. *Eur J Heart Fail* 2009;11:205–13
21. Dracup K, Evangelista LS, Hamilton MA, et al: Effects of a home-based exercise program on clinical outcomes in heart failure. *Am Heart J* 2007;154:877–83
22. Meyer T, Brooks A: Therapeutic impact of exercise on psychiatric diseases: guidelines for exercise testing and prescription. *Sports Med* 2000;30:269–79
23. Haddad M, Padulo J, Chamari K: The usefulness of session rating of perceived exertion for monitoring training load despite several influences on perceived exertion. *Int J Sports Physiol Perform* 2014;9:882–3
24. Sibillit KL, Berg SK, Hansen TB, et al: Effect of comprehensive cardiac rehabilitation after heart valve surgery (CopenHeartVR): study protocol for a randomised clinical trial. *Trials* 2013;14:104
25. Risom SS, Zwisler AD, Rasmussen TB, et al: The effect of integrated cardiac rehabilitation versus treatment as usual for atrial fibrillation patients treated with ablation: the randomised CopenHeartRFA trial protocol. *BMJ Open* 2013;3:e002377
26. Aamot IL, Forbord SH, Karlsen T, et al: Does rating of perceived exertion result in target exercise intensity during interval training in cardiac rehabilitation? A study of the Borg scale versus a heart rate monitor. *J Sci Med Sport* 2013;17:541–5
27. Uddin J, Zwisler AD, Lewinter C, et al: Predictors of exercise capacity following exercise-based rehabilitation in patients with coronary heart disease and heart failure: a meta-regression analysis. *Eur J Prev Cardiol* 2016;23:683–93
28. Zigmond AS, Snaith RP: The hospital anxiety and depression scale. *Acta Psychiatr Scand* 1983;67:361–70
29. Fleiss JL: Factorial experiments, in *The Design and Analysis of Clinical Experiments*. New York: John Wiley & Sons, Inc., 1999:306–47
30. Chen MJ, Fan X, Moe ST: Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *J Sports Sci* 2002;20:873–99