Clinical Rehabilitation 2005; **19:** 843–849

The effect of cardiac rehabilitation on recovery of heart rate over one minute after exercise in patients with coronary artery bypass graft surgery

Sen-Wei Tsai Department of Physical Medicine and Rehabilitation, Taichung Veterans General Hospital, Taichung and Department of Physical Therapy, HungKuang University, Taichung County, **Yi-Wen Lin** Department of Internal Medicine, Chung-Shan Medical University Hospital, Taichung and **Shyi-Kuen Wu** Department of Physical Therapy, HungKuang University, Taichung County and Institute of Biomedical Engineering, National Cheng Kung University, Tainan, Taiwan

Received 29th December 2004; returned for revisions 23rd March 2005; revised manuscript accepted 20th June 2005.

Objective: To evaluate the effects of cardiac rehabilitation on the recovery of heart rate over 1 min after peak exercise of patients who received coronary artery bypass graft (CABG) surgery.
Design: Thirty subjects who received CABG surgery were randomly assigned to enter or not enter a cardiac rehabilitation exercise programme (cardiac rehabilitation $n = 15$; control group $n = 15$).
Setting: Outpatient cardiac rehabilitation centre in a national medical hospital.
Interventions: Patients assigned to the cardiac rehabilitation group received 36 sessions of the exercise programme, three times a week, with the intensity designed to achieve an individual 60–85% peak heart rate in cardiopulmonary exercise test. Patients assigned to the control group did not get further advice about a specific exercise programme.
Main outcome measures: Resting heart rate and recovery of heart rate over 1 min after a peak exercise test at discharge and three months later were collected. The heart rates were analysed with computer-recorded electrocardiogram.
Results: At follow-up, the 15 patients in the cardiac rehabilitation group had a significantly lower resting heart rate (77.46 ± 9.49 versus 92.31 ± 10.18 bpm; $p < 0.001$) and a significantly higher recovery of heart rate over 1 min (16.38 ± 6.32 versus 11.38 ± 4.81 bpm; $p = 0.03$) compared with the control group. There were also significant reductions in resting heart rates (cardiac rehabilitation $p < 0.001$; control $p = 0.05$) and improvements in recovery on heart rate over 1 min (cardiac rehabilitation $p < 0.001$; control $p = 0.001$) compared with baseline measurements in both the cardiac rehabilitation and control groups.
Conclusion: Cardiac rehabilitation had a positive effect on the improvement of recovery on heart rate over 1 min in patients with coronary artery disease who received CABG surgery.

Address for correspondence: Shyi-Kuen Wu, No.34, Chung-Chie Rd., Salu, Taichung County, Taiwan 433. e-mail: skwu@sunrise.hk.edu.tw

10.1191/0269215505cr915oa

Introduction

Secondary prevention of coronary heart disease and increased exercise tolerance in patients who have received coronary artery bypass graft (CABG) are the main goals of cardiac rehabilitation. Phase II cardiac rehabilitation programmes are associated with significantly improved exercise tolerance and functional capacity, increased psychosocial well-being, alleviating activity-related symptoms, reducing disability and decreasing cardiovascular morbidity and mortality.[1–3] Tachycardia, a delegate of activation of sympathetic tone, is a common condition in patients who have just received CABG surgery. This phenomenon may be due to the damage of myocardial tissues, or a stress response to surgery, thus activating the sympathetic tone.[4–6] Reduced heart rate variability is a sign of autonomic dysfunction and has strong adverse effects on subsequent outcomes in patients with ischaemic heart disease. Data from Katona *et al.*'s studies of autonomic function on healthy people during exercise showed that increasing heart rate is due first to the withdrawal of parasympathetic tone, and then due to the activation of sympathetic tone.[5] In healthy people, exercise training can initiate a reset in the baroreflex to a higher blood pressure set point and decrease resting heart rate in young and ageing people.[6] During exercise, most of the heart rate increase up to 100 beats/min is caused by vagal withdrawal. Above a heart rate of 100 beats/min, heart rate is increased by sympathetic activation of cardiac adrenoreceptors by noradrenaline. After exercise, reactivation of the vagal tone causes the fall in heart rate.[7,8] Cardiac rehabilitation is associated with significant improvements in autonomic markers of neural regulation of the sinoatrial node, such as increase in R–R interval (derived from ECG recording), in its variance and in overall spontaneous baroreflex.[6,7]

Heart rate recovery immediately after exercise, a reflection of vagal activity, has been demonstrated to be a predictor of overall mortality.[8,9] That is, patients with fast recovery of heart rate over 1 min after peak exercise have a lower mortality rate compared with patients with slower heart rate recovery. A comprehensive cardiac rehabilitation programme offered to patients after coronary artery bypass surgery has been shown to improve the long-term prognosis and reduce the need for hospital care.[7,10–12] Lucini and colleagues proposed that the cardiac rehabilitation exercise programme is associated with significant improvement in the autonomic regulation of the sinoatrial node; however, the heart rate recovery was not addressed in their research.[7] Nishime and coworkers hypothesized that cardiac rehabilitation would favourably impact heart rate recovery by modulating autonomic function, but their results showed only the tendency of improved heart rate recovery after cardiac rehabilitation.[13] Kligfield and associates investigated the effect of age and gender on heart rate recovery in patients with stable angina or after myocardial infarction, coronary artery bypass surgery or percutaneous intervention. Although the recovery of heart rate increased after exercise training in men and women of all ages, the measurement of heart rate recovery was evaluated after the submaximal effort, not the peak exercise.[14]

Exercise training has been shown to modify the sympathovagal control of heart rate toward an increase in parasympathetic tone, and the improved vagal activity is associated with reduced death risk from cardiac events.[6,14] Although the cardiac rehabilitation exercise programme is a standard therapy for patients after a cardiac event, especially for people who have received CABG, the relationship between a cardiac rehabilitation exercise programme and heart rate recovery has not been clearly demonstrated.

The purpose of this study is to investigate if the phase II cardiac rehabilitation exercise programme has a positive effect on recovery of heart rate over 1 min after peak exercise in patients with CABG.

Methods

Thirty subjects receiving CABG surgery participated in this study. There were no patients with acute myocardial infarction. All the patients had pectoris angina with or without pulmonary oedema. Arteries used for bypass grafting were harvested from the radial artery. All the patients received a phase I cardiac rehabilitation programme, such as early mobilization and walking under supervision after surgery, immediately when

they were transferred to the intensive care unit. The clinical endpoint of this study is heart rate response.

Randomization design

Eligible patients referred by cardiovascular surgeons were randomly assigned to enter or not enter a phase II cardiac rehabilitation exercise programme in the Department of Physical Medicine and Rehabilitation of a medical center. Toss-of-coin was done independently by a rehabilitation nurse to make a randomization table. The sequence of CABG patients was determined by the date of surgery. Figure 1 shows the flowchart of randomization. The inclusion criteria were (1) subjects who had coronary artery disease without previous CABG surgery; (2) subjects without neurological impairments such as stroke, peripheral neuropathy or traumatic brain injury, (3) patients without musculoskeletal diseases such as spinal stenosis or joint contracture, (4) uncomplicated clinical course during hospitalization with no severe infection, shock, arrhythmia or prolonged ventilator-dependent phase. The subjects were excluded if (1) beta-blockers were used; (2) subjects refused to undergo the cardiopulmonary exercise test (CPET) at discharge and three months later; (3) uncontrolled dysrhythmias such as atrial flutter, fibrillation and continuous ventricular tachycardia were observed during exercise testing; (4) subjects could not complete the CPET at discharge or three months later; or (5) ischaemic change was observed on ECG during testing. Ethical approval was obtained from the Human Research Committee of the Taichung Veterans General Hospital, Taiwan.

The 30 subjects were randomly divided into two groups:

- *Group 1* (phase II cardiac rehabilitation group): 15 subjects completed a three-month phase II cardiac rehabilitation programme. Patients assigned to phase II cardiac rehabilitation began their programme within one week after discharge from hospital.
- *Group 2* (control group): 15 subjects who did not participate in the cardiac rehabilitation programme served as control subjects. Although they had received a phase I mobilization programme after surgery, patients assigned to control group did not get further advice about a specific exercise programme.

Exercise testing protocol

Subjects were tested by Oxycon Pro with a cycle ergometer (Jaeger Company, Germany) with one-minute incremental protocol.[15] The 12-lead ECG and blood pressure were continuously obtained with the patient in an upright position during the whole exercise testing period. After a 3-min rest period, subjects initially cycled for 3 min with a 10 W load for the baseline warm-up. Then an increment of 10 W/min protocol was used, and subjects were encouraged to continue exercise until peak symptoms were achieved, such as severe dyspnoea, dizziness, arrhythmia, abnormal ST segment elevation or depression, and decreased blood pressure over 20 mmHg. Subjects were advised to continue to pedal at a slow frequency with a 10 W load on the ergometer as the recovery phase, and continue to breathe through the

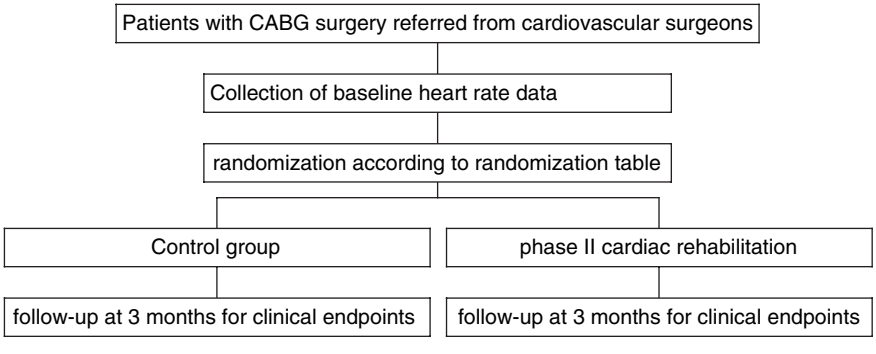

Figure 1 Flowchart of randomization of trial. The clinical endpoint is for resting heart rate and recovery of heart rate over 1 min after peak exercise.

mouthpiece for at least 3 min. The test procedures were fully explained to all subjects, and informed consent was obtained.

Cardiac rehabilitation

Subjects who participated in the phase II cardiac rehabilitation conducted a 30–40 min aerobic exercise training session (riding a stationary bicycle or walking on a treadmill) with the intensity of 60–85% peak heart rate achieved in cardiopulmonary exercise test.[2,7] There were approximately 10 min of stretching and calisthenics for warm-up and cool-down. The training frequency was three times a week and a total of 36 training sessions were completed by these subjects.

Recovery of heart rate on the first minute after exercise

After achieving peak stress exercise in cardiopulmonary exercise testing, subjects went into a recovery phase of at least 3 min. The reduction in heart rate from immediately after peak exercise to the heart rate after 1 min was defined as heart rate recovery. All 30 subjects received cardiopulmonary exercise tests at discharge (before phase II cardiac rehabilitation) and 12 weeks later (follow-up test).

Statistical analysis

The resting heart rate and recovery of heart rate over the first minute at baseline and follow-up were collected for comparison. The variables tested between the two groups were analysed and compared using analysis of variance (ANOVA). The paired t-test was used to calculate for the differences between the pre- and post-training variables within each group. Continuous variables were expressed as the mean $\pm$ standard deviation. Analyses were performed using the Scientific Package for Social Science version 10.1 (SPSS, Chicago, IL, USA). Statistical significance was considered as $p < 0.05$.

Results

The basic clinical characteristics of the two patient groups are presented in Table 1. The two groups were similar with regard to age, height, weight and basic medical history. There were no significant differences between two groups in age, and the mean ages for cardiac rehabilitation and control groups were 61.23 ± 9.49 and 63.23 ± 14.61 years, respectively ($p = 0.68$).

The descriptive statistics of the resting heart rate and recovery of heart rate over 1 min before rehabilitation and follow-up tests between two groups are also presented in Table 1. Heart rate was expressed as beats per minute (bpm). At the baseline testing, there were no significant differences in resting heart rates between cardiac rehabilitation (93.85 ± 10.32 bpm) and control groups (99.54 ± 7.30 bpm; $p = 0.12$). After three months, the cardiac rehabilitation group showed a significantly lower resting heart rate during the follow-up testing compared with that of the control group (77.46 ± 9.49 bpm versus 92.31 ± 10.18 bpm; $p < 0.01$).

Table 1 Basic clinical characteristics and descriptive statistics of resting heart rate and recovery of heart rate over 1 min before rehabilitation and at follow-up between two groups

	Cardiac rehabilitation	Control	*p*-value
Case number	$n = 15$	$n = 15$	
Age (years)	61.23 ± 9.49	63.23 ± 14.61	0.68
Height (cm)	167.69 ± 6.46	168.76 ± 8.07	0.71
Weight (kg)	69.69 ± 7.59	71.23 ± 7.12	0.39
Medical history			
Diabetic (%)	3 (20.0%)	4 (26.7%)	
Hypertension (%)	4 (26.7%)	5 (33.3%)	
Hyperlipidaemia (%)	3 (20.0%)	3 (20.0%)	
Resting heart rate (bpm) before rehabilitation	93.85 ± 10.32	99.54 ± 7.30	0.12
Resting heart rate (bpm) at follow-up	77.46 ± 9.49	92.31 ± 10.18	< 0.01*
Recovery over 1 min of heart rate before rehabilitation (bpm)	4.15 ± 3.74	4.62 ± 4.41	0.78
Recovery over 1 min of heart rate at follow-up (bpm)	16.38 ± 6.32	11.38 ± 4.81	0.03*

*ANOVA: $p < 0.05$.

Comparisons between resting heart rates across the time interval of the two tests demonstrated the significant differences for both cardiac rehabilitation ($p = 0.0003$) and control ($p = 0.05$) groups.

For the comparison of recovery of heart rate over 1 min after peak exercise before phase II cardiac rehabilitation, there was no significant difference between cardiac rehabilitation (4.15 ± 3.74 bpm) and control groups (4.62 ± 4.41 bpm; $p = 0.78$). The mean value of recovery of heart rate over 1 min at follow-up was significantly higher for the cardiac rehabilitation group (16.38 ± 6.32 bpm) when compared with that of control group (11.38 ± 4.81 bpm) at the follow-up test ($p = 0.03$).

A significant difference in recovery of heart rate over 1 min between baseline and follow-up testing was found for the cardiac rehabilitation group ($p < 0.01$). Our results also showed that the control group had a significantly higher magnitude of recovery of heart rate over 1 min at follow-up when compared with that at baseline ($p = 0.0010$).

Discussion

This study shows significant improvements in resting heart rate and recovery of heart rate over 1 min after exercise in CABG subjects after a three-month cardiac rehabilitation exercise programme. The reduced heart rate variability has been proposed to be major evidence of autonomic dysfunction, and is regarded to have strong adverse effects on subsequent clinical outcome in patients with coronary artery disease.[7–9,18–20] Our subjects demonstrated the higher resting heart rates at the baseline testing for both groups before the cardiac rehabilitation. This observation was close to the result of the Pardo's research,[21] but higher than that of a recent retrospective study.[19] The discrepancies may be due to higher resting heart rates of patients with coronary heart disease, suggesting the activation of neurohumoral mechanisms, especially the adrenergic activation from sympathetic activity in early recovery phase from cardiac events.[7,8,21] The subjects in Tiukinhoy's study[19] were evaluated with a 6 ± 3 months time interval for the cardiac rehabilitation group as well as 9 ± 3 months for the control group, and without information about the time of baseline testing. The early baseline measurement at discharge in the present study could account for the difference in resting heart rates.

The mean resting heart rate of the cardiac rehabilitation group at follow-up in this study was 77.46 bpm, which was consistent with the prior published studies.[20–22] The mean resting heart rate at follow-up, which was significantly lower in the cardiac rehabilitation group than in the control group, was similar to previous work.[20] This improvement of resting heart rate in the cardiac rehabilitation group may be due to long-term endurance training, which increases the parasympathetic activity and decreases the sympathetic activity directed to the human heart at rest, thus decreasing resting heart rate.[16–18,20,21] However, our finding was in contrast to the result of Tiukinhoy *et al*.[19]: their subjects did not show any improvement in resting heart rate at follow-up. Possible reasons may be the nearly normal resting heart rates for the control subjects at baseline and the long time interval between serial exercise stress tests. Pardo and co-workers reported that exercise conditioning over a 12-week period improved heart rate variability, reduced resting heart rate in cardiac patients, and lowered the risk of sudden cardiac death via increased vagal tone.[21]

Resting heart rates were significantly reduced in both groups at follow-up when compared with baseline data in the present study. The control group showed a marginally significant improvement in resting heart rates at follow-up, which may be explained by the study of Oya *et al*.[18] The sympathetic nervous system has been proposed to increase activity during the first three weeks after the onset of a cardiac event, whereas the parasympathetic nervous system has been observed to improve gradually during the three-month period.[6] It was concluded that time is a factor for the improvement in parasympathetic tone.[18]

Our subjects demonstrated a smaller recovery of heart rate over 1 min at the baseline testing in both cardiac rehabilitation and control groups compared with previous studies.[14,19] The heart rate recovery calculated in Kligfield's research[14] was measured as the difference between the heart rates at the end of 30 min of submaximal exercise training and after 1 min of cool-down. The subjects in Tiukinhoy's study[19] were evaluated with a longer time interval and without information about the

Clinical messages

- Three months of cardiac rehabilitation training in patients receiving coronary artery bypass grafts had significant improvements in heart rate recovery and resting heart rate.
- As an independent risk factor for mortality, the recovery of heart rate over 1 min may be a good parameter with which to assess the effectiveness of cardiac exercise training, and for risk stratification.

time of baseline testing. These discrepancies in the definition of recovery of heart rate and baseline measurement may account for the different results in baseline recovery of heart rate.

For the comparison between groups at follow-up, the mean recovery of heart rate over 1 min (16.38 bpm) in the cardiac rehabilitation group was significantly higher than in the control group and was similar to previous published works.[14,19] Kligfield and colleagues investigated the effect of age and gender on heart rate recovery during 12 weeks of phase II cardiac rehabilitation and concluded that the heart rate recovery increase in men and women of all ages was consistent with enhancement of parasympathetic tone.[14] The significantly higher recovery of heart rate over 1 min in the cardiac rehabilitation group in the present study was supported by the fact that endurance training has a positive effect on activation of parasympathetic tone.[13,14,16–19] Cardiac rehabilitation with exercise training alters sympathovagal control of heart rate variability toward parasympathetic dominance, and improves heart rate recovery.[14,19,22]

The recovery of heart rate over 1 min at follow-up also showed significant improvement in both the cardiac rehabilitation and control groups. In the present study, the improvement in heart rate recovery in the control group implied that the balanced sympathetic and parasympathetic tone might occur gradually after CABG surgery. This result was different from that reported in Tiukinhoy's research.[19] They observed no improvement in heart rate recovery in the control group, and no reduction in resting heart rate for the cardiac rehabilitation group. In addition to the different time intervals for baseline and follow-up tests, the usage of beta-blockers in over 70% of their subjects may be the reasons for the stable heart rate recovery of the control group. The most likely explanation for the improvement in the recovery of heart rate over 1 min in the control group in the present study was the spontaneous recovery of parasympathetic tone after a three-month period.[8,18]

Abnormalities of the autonomic nervous system are related to the mechanisms of sudden cardiac death, and an elevated heart rate at rest is confirmed as an independent risk factor for sudden death in normal middle-aged men.[23] The autonomic dysfunction is known to adversely affect clinical outcome in patients with cardiovascular disease, so the improvement in autonomic regulation after cardiac rehabilitation may add to the other proven benefits of exercise training programme.[7,13,18,22] The clinical implications of our study are that patients who received a three-month comprehensive cardiac rehabilitation exercise programme would get greater improvement in the reduction of resting heart rate and increase in heart rate recovery than those in the control group. The sympathetic and parasympathetic systems have been proposed to have a modulating effect on heart rate and heart rate variability. Our results are consistent with the improvement in autonomic regulation toward parasympathetic dominance in CABG patients after cardiac rehabilitation.

In our study, it is difficult to have a blind control in the cardiac group. In the control group, patients were told they would receive a cardiopulmonary exercise test three months later, and no further comments or suggestions for exercise were advised. Although the effect of cardiac rehabilitation is compelling and extensive, only 10–20% of eligible subjects participate in a formal cardiac rehabilitation programme.[24] In further studies the sample size in each group may expand and may be include different cardiac patients.

Acknowledgements

We would like to thank the biostatistical task force of Taichung Veterans General Hospital, Taichung, Taiwan, ROC, for their support for this study.

References

1 Ades PA. Medical progress: cardiac rehabilitation and secondary prevention of coronary artery disease. *N Engl J Med* 2001; **345**: 892–902.

2 Franklin B, Bonzheim K, Warren J *et al*. Effects of a contemporary, exercise-based rehabilitation and cardiovascular risk-reduction program on coronary patients with abnormal baseline risk factors. *Chest* 2002; **122**: 338–43.

3 Lan C, Chen SY, Hsu CJ *et al*. Improvement of cardiorespiratory function after percutaneous transluminal coronary angioplasty or coronary artery bypass grafting. *Am J Phys Med Rehabil* 2002; **81**: 336–41.

4 Ryan C, Hollenberg M, Harvery DB *et al*. Impaired parasympathetic responses in patients after myocardial infarction. *Am J Cardiol* 1976; **37**: 1013–18.

5 Katona PG, McLean M, Dighton DH *et al*. Sympathetic and parasympathetic cardiac control in athletes and nonathletes at rest. *J Appl Physiol* 1982; **52**: 1652–57.

6 Carter JB, Banister EW, Blaber AP. Effect of endurance exercise on autonomic control of heart rate. *Sports Med* 2003; **33**: 33–46.

7 Lucini D, Richard VM, Costantino G *et al*. Effects of cardiac rehabilitation and exercise training on autonomic regulation in patients with coronary artery disease. *Am Heart J* 2002; **143**: 977–83.

8 Robinson BF, Epstein SE, Beiser GD. Control of heart rate by the autonomic nervous system. *Circ Res* 1966; **19**: 400–11.

9 Cole CR, Blackstone EH, Pashkow FJ *et al*. Heart rate recovery immediately after exercise as a predictor of mortality. *N Engl J Med* 1999; **341**: 1351–57.

10 Messinger-Rapport B, Snader CEP *et al*. Blackstone EH. Value of exercise capacity and heart rate recovery in older people. *J Am Geriatr Soc* 2003; **51**: 63–68.

11 Hedback B, Perk J, Hornblad M *et al*. Cardiac rehabilitation after coronary artery bypass surgery: 10-year results on mortality, morbidity and readmissions to hospital. *J Cardiovasc Risk* 2001; **8**: 153–58.

12 Kavanagh T, Mertens DJ, Hamm LF *et al*. Prediction of long-term prognosis in 12,169 men referred for cardiac rehabilitation. *Circulation* 2002; **106**: 666–71.

13 Nishime EO, Cole CR, Wallace GS *et al*. Heart rate recovery improved in a cohort of adults after cardiac rehabilitation. *J Am Coll Cardiol* 2002; **39**: 164.

14 Kligfield P, McCormick A, Chai A *et al*. Effect of age and gender on heart rate recovery after submaximal exercise during cardiac rehabilitation in patients with angina pectoris, recent acute myocardial infarction, or coronary bypass surgery. *Am J Cardiol* 2003; **92**: 600–603.

15 Wasswerman K, Hansen JE, Sue DY *et al*. *Principles of exercise testing and interpretation*, third edition. Baltimore: Lippincott Williams & Wilkins, 1999: 115–42.

16 Shi X, Stevens G, Foresman BH *et al*. Autonomic nervous system control of the heart: endurance exercise training. *Med Sci Sports Exerc* 1995; **27**: 1406–13.

17 Wilmore JH, Stanforth PR, Gagnon J *et al*. Endurance exercise training has a minimal effect on resting heart rate: the heritage study. *Med Sci Sports Exerc* 1996; **28**: 829–35.

18 Oya M, Itoh H, Kato K *et al*. Effects of exercise training on the recovery of the autonomic nervous system and exercise capacity after acute myocardial infarction. *Jpn Circ J* 1999; **63**: 843–48.

19 Tiukinhoy S, Beohar N, Hsie M. Improvement in heart rate recovery after cardiac rehabilitation. *J Cardiopulm Rehabil* 2003; **23**: 84–87.

20 Mitu F, Mitu M, Pandele GI. The role of exercise testing in evaluation of functional capacity at patients with ischemic ventricular dysfunction. *Rev Med Chir Soc Med Nat Iasi* 2001; **105**: 89–93.

21 Pardo Y, Merz CN, Velasquez I *et al*. Exercise conditioning and heart rate variability: evidence of a threshold effect. *Clin Cardiol* 2000; **23**: 615–20.

22 Duru F, Candinas R, Dziekan G et al. Effect of exercise training on heart rate variability in patients with new-onset left ventricular dysfunction after myocardial infarction. *Am Heart J* 2000; **140**: 157–61.

23 Jouven X, Zureik M, Desnos M *et al*. Resting heart rate as a predictive risk factor for sudden death in middle-aged men. *Cardiovasc Res* 2001; **50**: 373–78.

24 Norris CM, Jensen LA, Galbraith PD *et al*. Referral rate and outcomes of cardiac rehabilitation after cardiac catheterization in a large Canadian city. *J Cardiopulm Rehabil* 2004; **24**: 392–400.