T

through the relief of myocardial ischaemia, the goal of cor

onary artery bypass grafting (CABG) is to preserve and if

possible to restore cardiac function towards normality.

Evaluation of cardiovascular haemodynamics has enhanced our

understanding of functional disability in cardiac patients, and

provided prognostic classification.1 It is therefore impor-

tant to investigate whether exercise rehabilitation following

CABG is able to confer further improvements in cardiac

performance as well as increasing functional capacity:

Exercise rehabilitation has been reported to improve the

prognosis,2 exercise capacity, and cardiac performance of

patients with coronary artery disease. The levels of cardiac

rehabilitation service provision within the UK are very

varied.3 We have therefore investigated whether a representa-

tive hospital based supervised cardiac rehabilitation pro-

gramme providing early, low level, and short term exercise

training can improve the cardiac and physical functional sta-

tus of patients post-CABG.

MET

HODS

We interviewed 100 patients who were on the waiting list for

CABG and found that only 22 of them expressed no preference

either for or against exercise rehabilitation following their

surgery. They performed a familiarising cardiopulmonary

exercise test. Six weeks postoperatively the patients were ran-

donised either to attend the hospital based exercise rehabilita-
	

tion programme or supervise their own recovery. Those in

the rehabilitation group attended once a week for six weeks.

On each occasion they completed 12 aerobic exercise stations

specifically designed to incorporate the use of different

skeletal muscle groups. Each week the level of exercise was

increased to incorporate more repetitions or a greater

workload. The patients performed a maximal cardiopulmo-

nary exercise test as previously described,4 one week before and

one week after rehabilitation. The supervisors of these tests

were blinded to the patient grouping. Those in the control

group were tested on an identical time scale. Ethical approval

and informed consents were obtained. Data from before and

after the study period were compared using the Student’s t

test for paired samples. A probability value of p < 0.05 was

considered significant.

RE

ULTS

The two study groups were similar in size and demographic

characteristics. All patients participating in the study com-

pleted the protocol. There were no deaths or major cardiac

events. There was 90% attendance at rehabilitation sessions.

Exercise test data are shown in table 1. At baseline both
groups demonstrated similar resting and exercise cardiopul-

monary responses. Following the six week study period, nei-

erther group showed any significant changes in resting

parameters. During exercise the mean (SD) rate of ventilation/

rate of oxygen uptake (VE/VO₂) at 1 litre/min of VO₂, and the

rate of ventilation/rate of carbon dioxide uptake (∆VE/∆CO₂) at 1

litre/min of VO₂ decreased significantly in the rehabilitation

group (28 (5) ∆V 26 (4) l/min and 33 (5) ∆V 31 (4) l/min, respec-

tively, both p < 0.05), but remained essentially unchanged in

the controls. There were significant increases in peak cardiac

output (CO, 11.3 (2.2) v 12.2 (1.7) l/min, p < 0.05), peak car-


diac power output (CPO, 2.97 (0.84) v 3.31 (0.7) W, p < 0.05),

and the overall cardiac reserve (1.92 (0.72) v 2.19 (0.53) W,

p < 0.05) in those who underwent formal rehabilitation. The

increases in the control group did not reach significance.

When comparing the magnitude of changes between the

groups, the increases were greater in the rehabilitation group

in all parameters, with the increment in peak CPO achieving

significance (0.34 (0.47) v 0.035 (0.21) W, p < 0.05). Exercise
time and peak VO₂ increased significantly in the rehabilita-

tion group (11.2 (3.6) v 13.2 (3.1) mins, p < 0.0001, and 20.5 (4.6)

v 22.3 (3.4) ml/kg/min, p < 0.0005) and also in the control

group (10.8 (4.9) v 12.3 (4.7) mins and 20.4 (6.4) v 22.7 (6.9)

ml/kg/min, respectively, all p < 0.005).

DISCUSSION

In this study we found that low intensity supervised exercise

training early postoperatively, typically provided in a UK

National Health Service hospital, in a cohort of patients who

expressed no preference for or against rehabilitation, did not

improve exercise capacity beyond that achieved by the corre-

sponding controls. Nevertheless, the same low level early

exercise rehabilitation had already shown improvements in

indices of cardiac and pulmonary function. Whether these

cardiopulmonary improvements will subsequently produce

greater exercise capacity with extended exercise programme

would require a further study.

Our results contrast with those of the only other randomised,

controlled study of a post-CABG population, in which the

trained group achieved a significant increase in peak VO₂, and a
decrease in submaximal heart rate.5 The training

sessions were more intense (85% of peak VO₂), more

frequent (three times a week), and continued for one year as

opposed to six weeks. One limitation of this study was that the

results could have arisen because the study was designed to

recruit only those individuals highly motivated to exercise.

Our results also contrast with those of other studies which

show that exercise training leads to a significant improve-

ment in exertional capacity and cardiac function in patients

with ischaemic heart disease.6 The training necessary to

achieve such improvements was either more frequent (for

every day), more prolonged (for example, one year), or both,

Abbreviations: CABG, coronary artery bypass graft; CO, cardiac

output; CPO, cardiac power output; VO₂, rate of carbon dioxide

production; VE, rate of ventilation; VO₂, rate of oxygen uptake
than in our study. Even those studies assessing “low intensity” training required patient attendance at least three times a week for two to three months. Hitherto, it has been unclear whether the provision of low level exercise training was of any benefit to patients. This study has shown that in terms of benefits in exercise capacity, such low levels are indeed insufficient, but it also showed that even at this low level of provision, structured exercise training produced objective benefits in terms of cardiac and respiratory function. There is therefore a need to conduct a dose–response study to ascertain what levels of exercise training are minimal and optimal to provide functional benefits.

The findings in this study suggest that the provision of cardiac rehabilitation post-CABG in many UK centres may be insufficient and needs to include more frequent exercise training sessions over a sustained period. Taking our results in conjunction with other studies, there is now overwhelming evidence of the beneficial effects of exercise training on functional capacity and cardiopulmonary function in patients with ischaemic heart disease; provided an adequate service is available.

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**REFERENCES**


**Table 1** Cardiopulmonary and haemodynamic variables, before and after the study period

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rehabilitation group</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>6 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise time (minutes)</td>
<td>11.2 (3.6)</td>
<td>13.2 (3.1)†</td>
</tr>
<tr>
<td>Peak VO2 (ml/kg/min)</td>
<td>20.5 (4.6)</td>
<td>22.3 (3.4)†</td>
</tr>
<tr>
<td>Anaerobic threshold (ml/min)</td>
<td>1240 (244)</td>
<td>1297 (236)†</td>
</tr>
<tr>
<td>RER</td>
<td>1.09 (0.08)</td>
<td>1.15 (0.1)</td>
</tr>
<tr>
<td>Rest heart rate (beats/min)</td>
<td>86 (15)</td>
<td>87 (12)</td>
</tr>
<tr>
<td>Peak heart rate (beats/min)</td>
<td>141 (19)</td>
<td>147 (18)</td>
</tr>
<tr>
<td>Rest mean blood pressure (mm Hg)</td>
<td>103 (14)</td>
<td>104 (14)</td>
</tr>
<tr>
<td>Peak mean blood pressure (mm Hg)</td>
<td>119 (14)</td>
<td>122 (12)</td>
</tr>
<tr>
<td>VO2/VCO2 at 1 litre VO2 (l/min)</td>
<td>28 (5)</td>
<td>26 (4)*</td>
</tr>
<tr>
<td>VE/VCO2 at 1 litre VCO2 (l/min)</td>
<td>33 (5)</td>
<td>31 (4)*</td>
</tr>
<tr>
<td>Rest CO (l/min)</td>
<td>4.59 (1.09)</td>
<td>4.83 (1.29)</td>
</tr>
<tr>
<td>Peak CO (l/min)</td>
<td>11.3 (2.2)</td>
<td>12.2 (1.7)*</td>
</tr>
<tr>
<td>Rest CPO (W)</td>
<td>1.05 (0.31)</td>
<td>1.12 (0.37)</td>
</tr>
<tr>
<td>Peak CPO (W)</td>
<td>2.97 (0.84)</td>
<td>3.31 (0.7)*</td>
</tr>
<tr>
<td>Cardiac reserve (W)</td>
<td>1.92 (0.72)</td>
<td>2.19 (0.53)*</td>
</tr>
</tbody>
</table>

Results are expressed as mean (SD).

*p<0.05, †p<0.005, at 6 weeks versus baseline.

CO, cardiac output; CPO, cardiac power output; RER, respiratory exchange ratio; VCO2, rate of carbon dioxide production; VE, rate of ventilation; VO2, rate of oxygen uptake.

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D J Wright, S G Williams, R Riley, P Marshall and L B Tan

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