Chapter 4
Training effects on peak VO$_2$, specific to the mode of movement in rehabilitation of patients with coronary artery disease

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ABSTRACT

Training effects on peak oxygen consumption (VO₂), specific to the mode of movement, are well-known in exercise training of young, healthy adults. However, these specific training effects were never studied in patients with coronary artery disease, but may be important in the evaluation of training effects of cardiac rehabilitation programs. Exercise training programs dominated by, for example, cycling might improve peak VO₂, measured during cycling, more than during treadmill testing. Therefore, the effects of an exercise training program dominated by cycling and of a program with both cycling and walking/jogging during a 6-weeks cardiac rehabilitation program were evaluated on both cycle ergometer and treadmill. Male patients (aged between 35 and 70 years) with coronary artery disease (history of myocardial infarction and/or angina pectoris and/or coronary artery bypass surgery) were randomly assigned to either a program dominated by cycling (Group I: n=18, mean age 53 ± 6.7) or a program with both cycling and jogging (Group II: n=20, mean age 48 ± 9.1). Before and after the program peak VO₂ was measured on both cycle ergometer and treadmill. At baseline peak VO₂ on treadmill was significantly greater than on cycle ergometer in both groups. Peak VO₂ (both cycle and treadmill) increased highly significant during both programs; in group I the increase of peak VO₂ on cycle ergometer was greater than on treadmill (respectively, 28.1% versus 18.8%; p<0.05), in contrast to group II (respectively, 22.8% and 16.6%; n.s.). As a result, the difference between peak VO₂ on treadmill and cycle ergometer decreased significantly more during the program in group I (p<0.05). These results suggest specific training effects in patients with coronary artery disease and should be considered outcome assessment and exercise prescription of cardiac rehabilitation programs.
INTRODUCTION

Most exercise training programs in cardiac rehabilitation are dominated by one mode of movement, in the Netherlands usually cycling. This might result into training effects specific to the mode of movement, influencing outcome assessment of cardiac rehabilitation programs. These specific training effects on peak VO2-measurements are well known in young healthy persons, but to what extent training effects specific to the mode of movement influences the outcome of cardiac rehabilitation has never been studied. Whether these effects are present to the same extent in older-aged, cardiac patients might be questioned, because exercise capacity and effects of exercise training are influenced by age and extent of cardiac disease (e.g. myocardial ischaemia, medication, systolic and diastolic left ventricular function, peripheral hemodynamics, metabolic changes in skeletal muscles).

In order to evaluate training effects specific to the mode of movement during a 6-week out-patient cardiac rehabilitation program, we compared the effects on peak VO2 (measured on both cycle-ergometer and treadmill) of an exercise training program dominated by cycling with a program with both cycling and walking/jogging.

METHODS

Study sample and design
Male patients (aged between 35 and 70 year) with coronary artery disease (history of myocardial infarction and/or angina pectoris and/or coronary artery bypass surgery) and referred to the cardiac rehabilitation centre, were eligible for this study. Exclusion criteria were: chronic obstructive pulmonary disease, restrictions in cycling or running due to orthopaedic, vascular and/or neurologic disease, systemic disease or contra-indications for physical exercise. Patients were randomly assigned to either a cycling-dominated exercise program (group I), or to an exercise program in which a balanced mixture of cycling and walking/jogging was given (group II). All patients supplied written informed consent for participation in the study. Patient characteristics of both groups are shown in table 1; there were no significant differences between both groups.

Before entering the study patients were familiarised with the test procedures and the instruments used to collect pulmonary gases, on both cycle ergometer and treadmill. Exercise capacity was measured at baseline and at the end of the 6-week exercise-training program on both cycle ergometer and treadmill. The order of cycle ergometer and treadmill exercise testing was randomly allocated; half the patients performed the cycle exercise test first, followed by the treadmill exercise test 3 days later, the other half did the tests in reverse order. The same sequence of exercise tests was used after the exercise training program. Both modes of exercise tests were performed between 9.00 and 10.30 AM.
Chapter 4
Specific Training Effects in Cardiac Rehabilitation

Specific training effects in cardiac rehabilitation

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
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<tbody>
<tr>
<td>n</td>
<td>18</td>
</tr>
<tr>
<td>mean age</td>
<td>53 ± 6.7</td>
</tr>
<tr>
<td>mean length</td>
<td>176.1 ± 5.10</td>
</tr>
<tr>
<td>mean weight before rehabilitation</td>
<td>77.7 ± 6.46</td>
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<tr>
<td>mean weight after rehabilitation</td>
<td>76.5 ± 6.30</td>
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</tbody>
</table>

Medical history

myocardial infarction
localisation: anterior | 5 | 10
inferior/posterior | 10 | 5

coronary surgery | 4 | 4
angina pectoris | 4 | 3

Medication

β-blocker | 6 | 8
calcium-antagonist | 8 | 1
nitrates (long-acting) | 4 | 5
digitalis | 1 | 1
ACE-inhibitor | 4 | 2

systolic blood pressure before rehabilitation | 122 ± 11.7 | 121 ± 16.8
after rehabilitation | 118 ± 11.9 | 115 ± 7.7

diastolic blood pressure before rehabilitation | 79 ± 7.8 | 75 ± 6.1
after rehabilitation | 75 ± 5.8 | 77 ± 5.7

heart rate (rest) before rehabilitation | 76 ± 15.7 | 72 ± 10.7
after rehabilitation | 74 ± 15.5 | 70 ± 13.4

Table 1: Clinical characteristics of both groups. Data presented are mean value ± SD or the number of patients.

Treadmill protocol

<table>
<thead>
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<th>minutes</th>
<th>speed (km.h⁻¹)</th>
<th>grade (%)</th>
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<tr>
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<td>13</td>
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until exhaustion

Table 2.
**Exercise testing**

Exercise tests were symptom-limited and performed according to international accepted guidelines for exercise testing\(^6\); patients were encouraged during the testing to reach maximal effort. Cycle exercise tests were performed in an upright position using an electromagnetically braked cycle ergometer (Corival 400; Lode, Groningen, the Netherlands). Exercise started with a 3-minute period with a workload of 20 Watt; after the initial workload power output was increased to 50 Watt and was subsequently raised by 10 Watt per minute until exhaustion. Patients were instructed to maintain a speed of 60 to 70 rotations per minute. Treadmill exercise tests were carried out on an Enraf Nonius treadmill (type 471; Delft, the Netherlands) and patients followed a modified Naughton protocol (table 2).

**Measurements**

The electrocardiogram was continuously monitored for heart rate, arrhythmias, and ST-segment displacement; a twelve-lead electrocardiogram recording was obtained at rest, every two minutes during exercise and during recovery (Mingophon 7; Siemens Elema, Erlangen, Germany). Blood pressure was measured by sphygmanometry pre-exercise, every two minutes during exercise and for 6 minutes post-exercise. Systolic rate pressure product was calculated by multiplying systolic blood pressure and heart rate, both assessed during peak effort. We defined the sub-maximal stage during final exercise testing, as the same stage or workload reached at peak exercise during baseline testing. Capillary blood samples were obtained within 10 seconds following peak exercise to determine the blood lactate concentration.

**Respiratory gas analysis.** Wearing a nose-clamp, patients breathed through a mouthpiece with a low-resistance two-way valve (Rudolph 2700) and plastic tubing. Expired gas was collected in an automated gas exchange measuring system (Oxycon type Ox-4; Mijnhardt, Breda, the Netherlands) and analysed for airflow, oxygen and carbon dioxide concentrations. VO\(_2\) and VCO\(_2\) were calculated and recorded at 30-second intervals for the entire exercise duration and during the first two minutes of recovery. The gas analysers were calibrated with a gas consisting of an analysed mixture of O\(_2\), CO\(_2\) and N\(_2\) and with 100% N\(_2\) gas prior to the exercise test, after a warm-up period of the gas-analysers of at least 30 minutes. Peak VO\(_2\) was defined as the mean of the VO\(_2\) values measured during the last minute of peak exercise.

**Exercise training program**

The exercise training program lasted 6 weeks with a frequency of 5 days a week in both groups. Mainstay of the program was an endurance training of half an hour, twice a day. In group I this endurance training was performed exclusively on a cycle ergometer, while in group II 30% of the cycling trainings were replaced by walking/jogging training. In addition to the endurance training both groups participated also in sports training each day, consisting various forms of exercise (e.g. callisthenics, swimming, badminton, table tennis, volleyball) and relaxation therapy. Additional parts of the cardiac rehabilitation program (i.e. education, individual counselling by psychologist, social worker or dietician) were also the same for both groups.
Cycle training. Each cycle training session incorporated 15 min. of continuous cycling and was preceded by a 5 min. warm-up and followed by a 5 min. cool-down period (cycle ergometer: Corival 300, Lode, Groningen, the Netherlands). Heart rate was monitored continuously using a CM5 lead (Servomed SMS 182; Hellige, the Netherlands) and the training intensity was adjusted so that a workload corresponding to the training heart rate could be maintained [based on Karvonen: training heart rate equals resting heart rate plus 60% (first three weeks) or 70% (last three weeks) of the heart rate reserve]\(^\text{16}\).

Walking/jogging training. In group II patients participated in the walking/jogging training three times a week. Each walking/jogging training session lasted 40 minutes (including 5 minutes preparation, 10 minutes warm-up, 20 minutes training, 5 minutes cool-down). Starting with interval-training the duration of the active periods were gradually increased, with all patients finally achieving endurance training. Training intensity was controlled by recording the heart rate (Polar heart rate monitor) and adjusted to maintain a comparable heart rate as in the cycle training.

Statistical analysis
Statistics were obtained using SPSS for personal computer statistical software package. Results are quoted as mean ± standard deviation. Changes in exercise parameters during the exercise program were tested with MANOVA for repeated measures. Differences between both groups were tested with ANOVA. Differences between peak VO\(_2\) on treadmill and peak VO\(_2\) on cycle ergometer were calculated. Changes of these differences during the program were tested with ANOVA with covariance, using baseline peak VO\(_2\) as covariant, because of baseline differences in peak VO\(_2\) between both groups. A \(p < 0.05\) level of statistical significance was chosen.

RESULTS
During the study period, medication remained unchanged, with exception of 5 patients; in group I: labetolol was increased due to persistent hypertension (patient 2) and a calcium antagonist (Isoptin) was replaced by a β-blocker (metoprolol) because of persistent myocardial ischaemia (patient 17); in group II a calcium antagonist was stopped due to side effects (patient 2) and a β-blocker was prescribed due to persistent myocardial ischaemia (patients 3 and 16). All patients reached subjective, maximal effort and in none of the patients exercise testing had to be stopped because of cardiac symptoms or adverse events.

Peak VO\(_2\)
At baseline, mean "treadmill" peak VO\(_2\) of both groups was significantly higher than mean "cycle" peak VO\(_2\) (table 3). Both treadmill and cycle peak VO\(_2\) increased highly significant in both groups during the exercise program (figure 2). In group I, the increase in cycle peak VO\(_2\) was significantly greater than the increase in mean treadmill peak VO\(_2\) (cycle versus treadmill: respectively 28.1 and 18.8%); as a consequence,
### Table 3: Mean physiological responses during maximal exercise before and after exercise training.

| Group 1 | before | bicycle | 22.84 ± 5.26 | 140.2 ± 24.1 | 180 ± 26 | 5.78 ± 1.20 | 1.10 ± 0.08 | 25436 ± 6710 |
|         | treadmill | 25.26 ± 5.25 | 141.3 ± 21.9 | 170 ± 27 | 5.50 ± 1.82 | 1.09 ± 0.09 | 24190 ± 6014 |
|         | after | bicycle | 29.25 ± 5.84 | 146.7 ± 24.1 | 128.9 ± 23.6 | 180 ± 23 | 7.04 ± 1.22 | 1.12 ± 0.07 | 26581 ± 6045 | 22172 ± 5278 |
|         | treadmill | 30.01 ± 6.39 | 146.3 ± 25.4 | 174 ± 18 | 6.96 ± 1.13 | 1.12 ± 0.10 | 25703 ± 6450 | 22038 ± 5810 |
| Group 2 | before | bicycle | 24.76 ± 4.81 | 145.1 ± 14.2 | 177 ± 24 | 5.82 ± 1.63 | 1.10 ± 0.08 | 25709 ± 4552 |
|         | treadmill | 28.30 ± 4.70 | 150.8 ± 17.9 | 158 ± 17 | 6.03 ± 2.95 | 1.10 ± 0.08 | 23889 ± 4237 |
|         | after | bicycle | 30.41 ± 4.71 | 153.5 ± 16.8 | 132.1 ± 19.0 | 185 ± 31 | 7.77 ± 1.22 | 1.12 ± 0.05 | 28467 ± 6411 | 21984 ± 4113 |
|         | treadmill | 32.99 ± 5.13 | 157.6 ± 16.3 | 164 ± 18 | 8.61 ± 1.80 | 1.12 ± 0.06 | 25891 ± 4820 | 22534 ± 4208 |

Data presented are mean value ± SD.

Significant differences (p<0.05):
- * after exercise training versus before exercise training
- ‡ treadmill exercise testing versus bicycle exercise testing

[ HR (max): heart rate at maximal work load; HRsub / RPP sub: heart rate / Rate Pressure Product determined during final exercise testing at the same workload as peak workload during exercise testing before exercise training; peak VO2*: peak oxygen consumption in (ml/min/kg); cLactate: concentration serum lactate in capillary blood at maximal workload; RER: respiratory exchange ratio at maximal exercise; RPP (max): rate pressure product at maximal work load; SBP: systolic blood pressure at maximal work load ].
treadmill peak VO\textsubscript{2} was no longer significantly greater than cycle peak VO\textsubscript{2} after the exercise program in group I. However, in group II the increase of cycle peak VO\textsubscript{2} was not significantly greater than treadmill peak VO\textsubscript{2}. Therefore, treadmill peak VO\textsubscript{2} remained significantly greater than cycle peak VO\textsubscript{2} during the program in group II. After the program the difference between treadmill and cycle peak VO\textsubscript{2} proved to be significantly greater in group II than in group I.
Rate Pressure Product (RPP) and blood lactate concentration

RPP at peak exercise was both before and after exercise training lower during treadmill exercise testing than during cycle exercise testing (only in group II significant) (table 3), due to a higher peak systolic blood pressure during cycling. In contrast, maximal achieved heart rate tended to be higher during treadmill exercise testing. Blood lactate concentrations at peak exercise demonstrated no significant difference between cycling and treadmill exercise testing both at baseline and at the end of the 6-week exercise training program. In comparison with baseline, blood lactate concentrations at peak exercise were significantly higher in both modes of exercise testing after the program.

Heart rate and RPP at a given workload were during the final exercise test lower than during baseline exercise testing. This is illustrated in table 3 by a significantly lower heart rate and RPP at the sub-maximal stage after the 6-week training program on both treadmill and cycle ergometer.

DISCUSSION

Training effects specific to the mode of movement

The presented data of this study demonstrates, that training effects specific to the mode of movement can be elicited also in patients with coronary artery disease. Training effects specific to the mode of movement might be the result of improved (motoric) skills, and strength and metabolism of the working muscles. In a cycling-dominated exercise program subjects will learn to improve their motoric skills for cycling. Especially in subjects unfamiliar with this type of movement, this learning phenomenon might be important. In most countries, the largest part of the population is unfamiliar with cycling. However, in the Netherlands almost everybody is familiar with this type of movement and learns to ride a bicycle at a young age. Therefore, a possible learning phenomenon might be more important in comparable populations in other countries. Frequent cycle training will strengthen the working muscles, especially the quadriceps muscles. Since in most cases a cycle exercise test is terminated due to muscular fatigue, improved performance on a cycle exercise test may be partly due to strengthened quadriceps muscles11,17,18.

Implications for outcome assessment

Specific training effects might be of particular interest in outcome assessment of cardiac rehabilitation programs. Most programs are dominated by one mode of movement and are likely to elicit specific training effects. These specific training may interfere with outcome assessment and cause an over- or underestimation of the training response of an exercise training program, depending on the mode of movement applied during both exercise training and testing. This should be recognised, when effects of different programs and studies are compared. However, outcome assessment should not only be adjusted to the exercise training program, but also to the normal daily activities to be resumed by the patient after the rehabilitation program.
Implications for tailored cardiac rehabilitation

Central theme in tailored cardiac rehabilitation is the individualised composition of programs, including the exercise program, but also the application of additional therapies (e.g. counselling by psychologist, dietician, or social worker). Exercise programs are until now only individualised by intensity, duration and frequency. However, also the mode of movement might be considered, because specific training effects might facilitate achievement of the goal of exercise programs during cardiac rehabilitation (i.e. improvement of physical capacity in order to restore normal daily function). Until now, most exercise programs are strongly dominated by one mode of movement, while in most patients in industrialised countries daily activities consist of a numerous mode of movements. This suggests, that exercise programs should be composed by various modes of movement in accordance with normal daily activities of patients. Only in patients with exceptional work or recreational activities, a program with domination of a certain mode of movement might be considered. For example, training effects specific to cycling might be beneficial to many of our patients, because cycling is a very common mode of transport and a common recreational activity in the Netherlands. In order to preserve the improved exercise capacity after finishing cardiac rehabilitation, patients should be motivated to continue physical training by recreational sports or exercise for a long period. However, patients might be discouraged, when their exercise capacity proves to be disappointingly decreased during these recreational activities. This might be prevented, if the mode of movement used during the exercise program is adjusted to these recreational activities, provoking a specific training effect.

Increase in peak $\text{VO}_2$

We observed a relatively high mean increase in peak $\text{VO}_2$ (cycle ergometry: 25.6%) after the exercise training program. Frequency and intensity of exercise training programs\textsuperscript{10,26} mainly determine the magnitude of the increase in aerobic capacity. Therefore, the high frequency and intensity of exercise training that we applied in our centre, also resulting into higher values heart rate and blood lactate concentration at peak exercise, could explain the high increase in observed mean peak $\text{VO}_2$. Other explanations, for example low initial exercise capacity or changes in medication, are unlikely. At baseline, the peak $\text{VO}_2$ was relatively high with a mean peak $\text{VO}_2$ on the treadmill exercise testing of almost 85% of predicted\textsuperscript{15}. Medication was changed in only five patients.

Rate Pressure Product (RPP)

Increase of exercise capacity was also reflected by other parameters. For example, the heart rate - workload curve and RPP-workload curve were shifted to the "right" (i.e. to a higher workload) during the final exercise tests, both treadmill and cycle. However, training specificity on these parameters could not be shown. These parameters are of particular importance in exercise programs for patients with coronary artery disease, because both heart rate and systolic blood pressure are main determinants of myocardial $O_2$ demand. A reduced increase of RPP during exercise reflects a higher ischaemic threshold. As a consequence, exercise-induced angina is diminished.
Peak RPP was in both groups lower during treadmill exercise test. This difference was caused mainly by a higher systolic blood pressure in cycling peak exercise and was observed already in other studies\textsuperscript{6}. This indicates, that cycling evokes a greater pressor effect at peak exercise than walking or jogging. This pressor effect might be a response to more prominent isometric contractions, superimposed on dynamic contractions, which might be elicited in cycling to a greater extent than during walking and jogging.

**Study limitations**
Mainstay of our exercise program was endurance training by either cycling or walking/jogging. However, effects of both programs were assessed by measuring peak VO\textsubscript{2}. Peak VO\textsubscript{2} is preferred in most studies, because it is widely accepted as an objective parameter of exercise capacity\textsuperscript{5,6,12,13,24}. It might be suggested, that endurance training might have different effects on endurance and peak exercise capacity\textsuperscript{26}. Therefore, lactate or ventilatory threshold might be used in assessment of the effects of exercise programs. Disadvantage of the lactate threshold is the invasive character, which would certainly have a negative influence on the co-operation and compliance of patients in this study. Therefore, the use of the ventilatory threshold should be preferred, but this is hampered by the necessity of expensive, modern gas-analysers.

**CONCLUSION**
Exercise training programs in patients with coronary artery disease might elicit training effects on peak VO\textsubscript{2} specific to the mode of movement. These specific training effects should be considered in composing a tailor-made, or individualised, exercise program in cardiac rehabilitation, by adjusting the mode of movement during exercise programs to those physical activity, that patients will perform after cardiac rehabilitation. In addition, the specificity of peak VO\textsubscript{2} measurements should be taken into account when evaluating the effects of cardiac rehabilitation programs.

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References


