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Effect of exercise training in patients with an implantable cardioverter defibrillator

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Aims Little research exists on exercise performance and training in patients with an implemented cardioverter defibrillator (ICD) and only in a limited number of patients. This study aims to investigate the effect of exercise training in ICD patients in comparison to the effects in other cardiac patients without an ICD.

Methods and results 92 ICD patients were compared with a control group of 473 patients. A maximal cycle-spiroergometric test was performed until exhaustion before and after an ambulatory exercise training programme. Exercise training was offered 3 times a week for 3 months. The cut-off heart rate was set at (ICD detection rate −20 beats/min). At baseline, the ICD patients had a lower peak oxygen uptake (VO_2) compared to the control group. Training effects were smaller for peak VO_2 (mL/min/kg) and oxygen pulse in the ICD group (18 vs. 27%, $p = 0.006$ and 11 vs. 17%, $p = 0.016$, respectively). Several appropriate shocks were delivered during ($n = 5$), and in between ($n = 7$), testing or training and one inappropriate shock during training.

Conclusions ICD patients can safely participate in an exercise training programme with favorable results. A randomised control study with evaluation of the physical and the psychosocial effects is warranted.

Introduction

Since 1994 more and more patients with malignant ventricular arrhythmias are treated by implantation of an implantable cardioverter defibrillator (ICD), which reduces the risk of sudden death.[1–4] However, the referral from hospitals to cardiac rehabilitation centres is still

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negatively influenced by the fear of inappropriate shock delivery during exercise.

The beneficial effects of cardiac rehabilitation in terms of secondary prevention and on physiological and psychosocial functioning of cardiac patients in general are well-established.[5] Some recommendations are available for exercise testing and training in cardiac patients with ICD[6–8] or in patients at risk for malignant ventricular arrhythmias.[9–11] Nevertheless, very few studies have reported on the safety and feasibility of exercise training and on the effects of physical training in patients with ICD.[12–14]

Friedman et al.[13] described two cases of patients with ICD, who were included in a cardiac rehabilitation programme in 1996. The first clinical study was published in 2001 and compared exercise performance and the effect of physical training in ICD patients ($n = 8$) with a matched cardiac control group ($n = 16$).[14] Finally, a very recent paper reported on the effects of a comprehensive cardiac rehabilitation programme in comparison to usual care in 11 patients with ICD.[12] The preliminary results from these small studies indicated that exercise testing and training was feasible and safe in patients with ICD and that physical training increased their exercise performance. These studies, however, were performed in a very limited number of patients and it was generally acknowledged that the results needed confirmation from a larger cohort of patients.

The aim of the present study is to test, in a larger sample, the hypothesis that exercise training in ICD patients could lead to similar benefits as in other cardiac patients. Exercise performance and the effect of a 3-month exercise training programme were compared in a large group of patients with and without ICDs.

Methods

Patients

All patients ($n = 106$) with an ICD referred to the ambulatory cardiac rehabilitation programme at the Department of Cardiovascular and Respiratory Rehabilitation of the Rijnlands Rehabilitation Centre in Leiden (The Netherlands) and to the Cardiovascular Rehabilitation Unit of the University Hospitals of Leuven (Belgium) were recruited for the present analysis. Because comparison of ICD patients from both settings did not reveal any differences in patient characteristics, baseline exercise performance or in the intensity, frequency and effects of physical training, all patients with ICD were pooled together. The time-frame for recruitment of the ICD patients was 1996–2001 and the delay between ICD-implementation and the start of the rehabilitation programme ranged from 1 to 232 weeks with a median of 7 weeks. The control group was constructed from a large database of 2688 cardiac patients who were referred to the cardiac rehabilitation at the University Hospitals in Leuven. All patients who performed maximal exercise testing before and after a 3-month training programme were eligible for the present study ($n = 1942$). From this cohort, all patients within the same time of inclusion in the training programme, range for age, body height, weight, and body mass index as the ICD patients were selected as controls. Informed consent from the patients and approval from the Ethics Committee of the Faculty of Medicine for this study was obtained.

Implantable Cardioverter Defibrillators

All ICDs were third or fourth generation tiered therapy devices, capable of delivering shock therapy in a "VF zone" and of anti-tachycardia pacing and shock therapy in 1 or 2 ventricular tachycardia "VT-zones". The ICDs were single-chamber, dual-chamber or three-chamber (bi-ventricular) devices and were capable of storing electrocardiograms during events.

Exercise testing

The maximal exercise tests on the bicycle ergometer (Ergometrics 800S®, Ergometrics, Bitz, Germany) were performed in a laboratory where room temperature was stabilised at 18–22 °C. The initial workload of 20 W (Leuven) or 5 W (Leiden) was increased by 20 W every minute until exhaustion or until reaching a heart rate threshold in the ICD group. This threshold was set at the detection rate of the lowest zone in which therapies were programmed minus 20 beats/min.

Systolic and diastolic blood pressure were measured every 3 min (STBP-780®, Colin, Komaki, Japan or Bosotron 2®, Bosch and Sohn, Germany). Heart rate, a 12-lead electrocardiogram (Max Personal Exercise Testing®, Marquette, Wisconsin, USA or Jaeger Stress Test System, Mijnhardt, Bunnik, The Netherlands) and respiratory data (STPD: "standard temperature pressure dry" conditions of the gas) through breath-by-breath analysis (Oxycon Alpha® or Oxycon Pro®, Jaeger, Mijnhardt, Bunnik, The Netherlands) were registered continuously. Pulmonary ventilation was measured by means of a turbine flow meter. The gas analysers and the flow meter were calibrated before each test according to the manufacturer's instructions. Oxygen uptake (VO_2) and carbon dioxide output (VCO_2) were determined from the continuous measurement of oxygen and carbon dioxide concentration in the inspired and expired air. The respiratory gas exchange ratio (carbon dioxide output/oxygen uptake; RER), ventilatory equivalent for oxygen (pulmonary ventilation/oxygen uptake) and oxygen pulse (oxygen uptake/heart rate) were calculated.

Exercise training

In both locations an ambulatory supervised exercise training programme was offered for a period of 3 months with a recommended frequency of 3 times a week. Each session of 90 min consisted of cycling, running, arm ergometry, rowing, callisthenics, strength training and relaxation. In Leuven, the exercise intensity was individually determined for each patient by calculating an interval for training heart rate, using the formula of Karvonen: resting heart rate + 60–90%(peak heart rate − resting heart rate). In Leiden, exercise intensity was set at 50–80% of maximal intensity. When no inappropriate arrhythmias or cardiac events occurred after 6 weeks in Leiden, outdoor activities such as walking and jogging, strength endurance training and recreational sports were added to the training programme. ICD patients were limited by a maximal heart rate during training (ICD detection rate minus 20 beats/min). All patients were offered 4–5 informative modules in which information was given by the cardiologist, psychologist, social workers, dietician and physiotherapist.

Statistical methods

Data were analysed by using SAS statistical software version 8.0 for windows (Sas Institute Inc, Cary, NC, USA). Data are reported as means ± SD or as number of patients and frequency rate for dichotomous variables. Comparisons were made by means of paired and unpaired Student's *t* tests or by the Wilcoxon signed rank test. Categorical data were tested by χ^2 or by Fisher's exact test where appropriate. Regression analyses were performed on the study cohort of 1942 patients to determine whether ICD was associated with exercise performance or with its change after training. First, the unadjusted association between ICD and the dependent variables, peak VO_2, absolute and relative change in peak VO_2 (respectively) after training was determined. Second, multiple regression analyses were performed to adjust the influence of ICD for other determinants of the dependent variables, which had been identified by means of a stepwise selection procedure. The following list of independent variables were included in this procedure: age, body mass index, gender, underlying heart disease and interventions, family history of heart disease, hypertension, previous and current smoking habits, dyspnoea, angina pectoris, systolic and diastolic blood pressure at rest, resting heart rate, peak heart rate, ST depression during exercise testing, arrhythmia, training intensity and frequency and having a cardioverter defibrillator implantation. The significance level was 12.5% for inclusion and 5% for exclusion from the stepwise building procedure. All statistical tests were two-sided at a significance level of 5%.

Results

Patient characteristics

Four patients dropped out of the rehabilitation programme after moving to another city and six patients stopped because of non-cardiac co-morbidity. Four patients decided to terminate rehabilitation after receiving shocks for ventricular tachycardia. Data of the remaining 92 ICD patients were compared with those of a selected control group ($n = 473$). All patients performed baseline exercise tests and the re-evaluation tests after 3 months. Table 1 shows the characteristics of the patients with ICD, the control group and a reference group (all other patients from the cardiac rehabilitation database with maximal testing at baseline and at 3 months). Cholesterol level was higher and the incidence of ST-depression and former smoking were more frequent in the control group than in ICD patients. More ICD patients had complaints of dyspnoea in daily life. Left ventricular ejection fraction was measured in 34 ICD patients and in 320 patients in the control group. 23 ICD patients had an ejection fraction $\leqslant 40\%$ compared to 41 patients from the control group (68% vs 13%, $p < 0.001$). Overall intake of drugs with negative chronotropic effect was not significantly different between patients with ICD and controls (82% vs. 86%, $p > 0.05$). Amiodarone was taken more often in the ICD group (24% vs. 3%, $p < 0.001$), whereas β-blockers were more frequently used in the control group (55% vs. 78%, $p < 0.001$). There was no difference in the ingestion of calcium antagonists or digitalis between both groups.

Baseline exercise testing

The results of the baseline exercise tests are presented in Table 2. All patients interrupted the exercise test for reasons of exhaustion. The pre-determined heart rate

Table 1 Patient characteristics

Variable	Control	ICD	*p*-Value	Total cohort
Number of patients (m/f)	473 (428/45)	92 (79/13)	0.18	1942 (1797/145)
Age (years)	56 ± 7.8	57 ± 12	0.37	55 ± 9.3
Body mass index (kg m^{-2})	25.4 ± 2.8	25.9 ± 3.5	0.79	25.4 ± 3.1
Underlying heart disease				
Ischaemic heart disease				
AMI	351 (74%)	63 (68%)	0.26	1277 (66%)
CABG	116 (25%)	20 (22%)	0.57	712 (37%)
PTCA	109 (23%)	25 (27%)	0.39	558 (29%)
Valvular disease (artificial replacement)	29 (6%)	6 (5%)	0.80	101 (5%)
Cholesterol level (mg/100 ml)	226 ± 48	212 ± 40	0.009	223 ± 44
History of hypertension	115 (24%)	19 (20.6%)	0.45	495 (25.5%)
Family history for IHD	88 (19%)	14 (15%)	0.44	415 (21.4%)
ST-depression during exercise testing	80 (17%)	2 (2%)	0.001	288 (15%)
Smoking habits				
Current smoking	32 (7%)	7 (8%)	0.77	116 (6%)
Past smoking	371 (78%)	54 (59%)	0.001	1450 (75%)
Complaints in daily life				
Dyspnoea	71 (15%)	27 (29%)	0.001	335 (17%)
Angina pectoris	30 (6%)	3 (3%)	0.25	110 (6%)

Data are presented as mean ± SD, as number of patients and frequencies for dichotomous variables and as the *p*-value of the difference in patient characteristics between both groups. Comparisons of continuous variables between groups are made by means of unpaired *t* test or Wilcoxon signed rank test; χ^2 or Fisher's exact test was used for comparison of dichotomous variables. ICD, implantable cardioverter defibrillator; AMI, acute myocardial infarction; CABG, coronary artery bypass graft; PTCA, percutaneous transluminal coronary angioplasty; IHD, ischaemic heart disease.

Table 2 Results of the baseline exercise test

Variable	Control group ($n = 473$)	ICD group ($n = 92$)	p-Value
Data at rest and submaximal exercise			
Heart rate (beats min^{-1})	67 ± 12	67 ± 13	0.91
Systolic blood pressure (mmHg)	129 ± 19	132 ± 24	0.24
Diastolic blood pressure (mmHg)	80 ± 12	81 ± 12	0.31
Heart rate at 80 W (beats min^{-1})	105 ± 16	101 ± 19	0.10
Data at peak exercise			
VO_2 (ml min^{-1})	1705 ± 466	1417 ± 539	0.0001
VO_2 (ml min^{-1} kg^{-1})	22.2 ± 5.6	17.7 ± 6.1	0.0001
Oxygen pulse (ml $beat^{-1}$)	13.3 ± 3.1	12.4 ± 4.9	0.0002
Heart rate (beats min^{-1})	128 ± 22	117 ± 23	0.0001
RER (VCO_2VO_2)	1.10 ± 0.10	1.08 ± 0.13	0.10
V_EO_2 (V_E/VO_2)	36.2 ± 6.7	39.6 ± 8.4	0.0002

Data are presented as mean ± SD and as the p-value of the difference in the baseline result between both groups. Comparisons between groups are made by means of unpaired t test or Wilcoxon signed rank test. ICD, implantable cardioverter defibrillator; VO_2, oxygen uptake; RER, respiratory gas exchange ratio; VCO_2, carbon dioxide output; V_EVO_2, ventilatory equivalent for oxygen; V_E, ventilation.

Table 3 Absolute changes after physical training

Variable	Control group ($n = 473$)	ICD group ($n = 92$)	p-Value
Changes at rest and sub-maximal exercise			
Heart rate (beats min^{-1})	−1.4 ± 11.5*	0.3 ± 11.6	0.43
Systolic blood pressure (mmHg)	−0.8 ± 17.1	−2.8 ± 24.2	0.44
Heart rate at 80 W (beats min^{-1})	−5.5 ± 12.4#	−0.33 ± 15	0.01
Changes at peak exercise			
VO_2 (ml min^{-1})	408 ± 300#	246 ± 304#	0.0001
VO_2 (ml min^{-1} kg^{-1})	5.6 ± 4.0#	2.6 ± 3.5#	0.0001
Oxygen pulse (ml $beat^{-1}$)	2.1 ± 2.2#	0.9 ± 3#	0.0004
Heart rate (beats min^{-1})	8.8 ± 15.7#	8.8 ± 17.3#	0.99

Data are presented as mean ± SD and as the p-value of the difference in the change with training between both groups. Comparisons within groups are made by means of paired t test and between groups by means of unpaired t test or Wilcoxon signed rank test. ICD, implantable cardioverter defibrillator; VO_2, oxygen uptake. * $p < 0.01$, # $p < 0.001$, as compared between the first and second exercise test in each group.

threshold in ICD patients was not reached. There was no difference in resting heart rate or blood pressure between ICD and control patients. Submaximal (80 W) heart rate was similar, but heart rate at peak exercise was significantly lower in patients with an ICD than in the control group. Peak VO_2 and peak oxygen pulse were significantly lower in ICD patients. The ventilatory equivalent for oxygen at peak exercise was higher in ICD patients; RER was comparable.

Data after training

Training frequency averaged 2.1 ± 0.6 and 2.3 ± 0.5 times per week for the ICD and control group, respectively (p = NS). Training intensity in ICD patients and controls was similar (84.2 ± 11.7% vs. 82.6 ± 11.9%). The latter was calculated as: (training heart rate/peak heart rate) × 100, where the mean training heart rate during cycling and running of the last three training sessions and the peak heart rate of the second exercise test were used.

Absolute training-induced changes are illustrated in Table 3, relative changes in Fig. 1. Both the ICD and control group significantly increased VO_2, oxygen pulse and heart rate at peak exercise ($p < 0.001$). At three months peak VO_2 (1684 ± 587 vs. 2113 ± 549 mL/min or 20.5 ± 6.4 vs. 27.8 ± 6.9 mL/min/kg) and peak oxygen

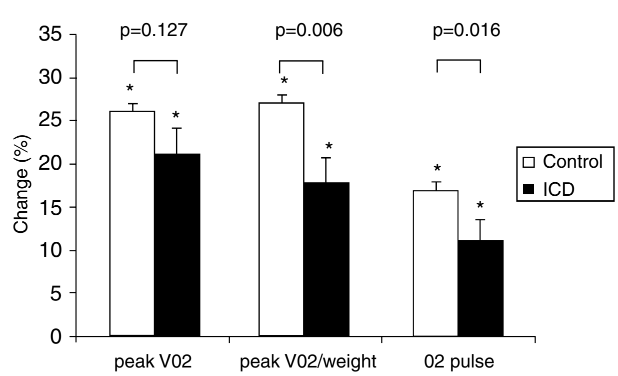

Fig. 1 Effect of physical training on the peak VO_2 in mL/min (left), peak VO_2 in mL/min/kg (middle) and oxygen pulse (right) in controls (white) and in patients with ICD. Data are represented as the mean relative increases from baseline to post-training ± SDs. Comparisons are made by means of the paired t test (within groups; represented by the asterisk symbol) and the unpaired test (between groups; represented by p-values). * $p < 0.001$ as compared between the first and second exercise test in each group.

pulse (13.3 ± 4.4 vs. 15.4 ± 3.5 mL/beat) remained lower in patients with ICD ($p < 0.001$). ICD patients made smaller absolute improvements in aerobic power compared with controls ($p < 0.001$). Relative improvements of peak VO_2 (mL/min/kg) and oxygen pulse were also smaller in patients with ICD ($p < 0.01$ and $p < 0.05$, respectively). Relative changes in peak VO_2 (mL/min) were not significantly different between groups. Body weight in ICD patients was, however, increased over three months by 2.2 ± 3.5 kg ($p < 0.001$), in contrast to controls ($p < 0.001$) who decreased weight by 0.4 ± 3.3 kg ($p < 0.01$). There were no differences between ICD and control group in training-induced changes in systolic blood pressure or in resting and peak heart rate. Heart rate at a submaximal workload (80 W) was decreased more in controls.

Regression analysis

The results of the single and multiple regression analysis for investigation of the relation between ICD implantation and the dependent variables peak VO_2 (mL/min) at baseline and its changes after training are shown in Table 4. An inverse relation ($p < 0.001$) was observed between ICD and peak VO_2 as well as its absolute change, which remained strong ($p < 0.001$ and $p < 0.066$, respectively) after correction for many other determinants (such as age, gender, anthropometric characteristics, medical conditions, symptoms, drug regimen, interventions, smoking habits), ICD was also related to the relative changes in peak VO_2 ($p < 0.05$), but significance was lost with correction.

Arrhythmias during testing

Ventricular premature beats in couplets, triplets or runs occurred significantly more, both at the baseline and second exercise test ($p < 0.05$ and $p < 0.01$, respectively) in patients with ICD ($n = 16$ (17%) and $n = 18$ (20%), respectively) than in the control group ($n = 47$ (10%) and $n = 47$ (10%), respectively). Supra-ventricular premature beats at the baseline and second exercise test were less frequent ($p < 0.05$ and $p < 0.01$, respectively) in patients with an ICD ($n = 12$ (13%) and $n = 9$ (10%), respectively) than in the control group ($n = 112$ (24%) and $n = 112$ 24%, respectively). In either group the incidence of arrhythmias at baseline was similar to the incidence after training.

Events

Three ICD patients did not finish the rehabilitation programme after receiving appropriate shocks for ventricular tachycardia during exercise and one patient, did not finish the programme after experiencing multiple shocks some days following exercise training. From the remaining 92 patients, one patient with an ICD developed ventricular tachycardia during exercise testing without defibrillator shock intervention of the device and without adverse clinical manifestations but requiring over-pacing. Another ICD patient experienced asymptomatic ventricular tachycardia at 170 beats/min during training,

Table 4 Single and multiple regression analysis of peak VO_2 and the change after training

Independent variables entered in the model	Dependent variable					
	Peak VO_2 (ml/min)		Absolute change in peak VO_2 (mL/min)		Relative change in peak VO_2 (mL/min)	
	R^2 model	Partial R of ICD (p-value)	R^2 Model	Partial R of ICD (p-value)	R^2 model	Partial R of ICD (p-value)
ICD	0.016**	−0.126 (0.0001)	0.011**	−0.105 (0.0001)	0.002*	−0.045 (0.046%)
ICD + age, sex, BMI	0.334**	−0.118 (0.0001)	0.079**	−0.281 (0.0001)	0.013**	−0.032 (0.134%)
ICD + age, sex, BMI + other significant covariates[a]	0.396**	−0.122 (0.0001)	0.188**	−0.045 (0.049)	0.153**	−0.045 (0.076%)
ICD + age, sex, BMI + other significant covariates[a] + significant medications[b]	0.408**	−0.078 (0.0007)	0.202**	−0.045 (0.066)	0.164**	−0.032 (0.148%)

Data are presented as the R^2 of the full regression model including all independent variables and as the partial correlation co-efficient (R) of cardioverter defibrillator implantation (ICD) in this model, determined by single and multiple regression analysis for the dependent variables peak oxygen uptake (peak VO_2) and the absolute and relative changes in peak VO_2 after training. BMI, body mass index.

[a]For peak VO_2, other significant co-variates were dyspnoea or *angor pectoris* during daily life activities, previous smoking habits, resting heart rate at baseline, PTCA, coronary artery bypass grafting, heart transplantation, other cardiac surgery, co-morbidities, diabetes and claudication. For absolute change in peak VO_2, other significant co-variates were training intensity and frequency, dyspnoea during daily life activities, current smoking habits, resting heart rate at baseline and after training, resting systolic blood pressure, coronary artery bypass grafting, other cardiac surgery, exercise-induced ST depression and claudication. For relative change in peak O_2, other significant covariates were training intensity and frequency, dyspnoea during daily life activities, current smoking habits, resting heart rate at baseline and after training, PTCA, exercise-induced ST depression.

[b]For peak VO_2, significant medications were β-blockers, angiotensin conversion enzyme inhibitors, anti-arrhythmics, digitalis and diuretics. For absolute change in peak VO_2, significant medications were anti-platelets, digitalis and diuretics. For relative change in peak VO_2, significant medications were β-blockers, digitalis and diuretics.

*$p < 0.05$.

**$p < 0.001$.

with intervention of the device. During training one patient received an inappropriate shock requiring no further treatment. Between training sessions, the ICD delivered appropriate therapy shocks after ventricular tachycardia in 6 cases. No inappropriate treatments were delivered outside the training sessions.

Discussion

At present, very little research has been completed on exercise performance and the effect of training in patients with an ICD. Only a few papers, on a limited number of patients, described exercise training in ICD patients[12–14] indicating that exercise testing and training may be feasible and safely performed in patients with ICD. The need for larger studies, however, was generally recognised. Therefore, the aim of this study was to test the hypothesis that exercise training in ICD patients could result in similar benefits as in other cardiac patients in a larger cohort.

Exercise performance at baseline was lower in ICD patients, which could possibly be related to the higher incidence of a decreased LVEF in this group. From multiple regression analysis in the total database, ICD implantation was confirmed to be an independent determinant of aerobic power in cardiac patients. The respiratory exchange ratio at peak exercise indicates both groups achieved similar levels of exhaustion. The lower heart rates during exercise in ICD patients in this study are not due to differences in the intake of drugs with negative chronotropic properties.

Psychosocial well-being is an important aspect to consider when working with ICD patients, and could not be assessed in this study. The incidence of anxiety in this patient population is high, with approximately 24–87% of the patients experiencing increased symptoms of anxiety. The diagnostic rates for clinically significant anxiety disorders range from 13% to 38%.[15] It has been established that in patients with an ICD, fear of exercise is increased because of their concern for ICD discharges, which thus causes them to limit their everyday activities.[16] One report introduced the idea of "catastrophic cognitions", meaning that patients with high anxiety scores tend to interpret physical symptoms as signs of danger.[17] As physical activity causes a lot of physical sensations, it is possible that activities requiring considerable effort are avoided by these patients. This relative inactivity would result in physical deconditioning which in turn could at least partly explain the lower baseline level in exercise performance in ICD patients. It has been suggested that psychological interventions utilising cognitive behavioural aspects could reduce symptoms of anxiety.[16,18] Regarding the patient's well-being and general functioning, this would improve the health-related quality of life and be of benefit for the patient's physical fitness as well.[16]

Aerobic power significantly improved after 3 months of cardiac rehabilitation in both groups. The 21% improvement in peak VO_2 (mL/min) in the ICD group is comparable to the 20% improvement described in a previous study.[14] Fitchet et al.,[12] also described 11 ICD patients able to increase treadmill exercise duration by 16% after 3 months of comprehensive cardiac rehabilitation, whereas no changes had occurred over a similar period of 'usual care' which preceded rehabilitation.

For unclear reasons patients with an ICD increased in body weight with physical training, whereas controls decreased in weight. Part of the increase in peak VO_2 (mL/min) in ICD patients was thus probably related to increased body weight. This may explain why peak VO_2, adjusted for body weight, more clearly revealed the differences in the trainability of aerobic power between both groups, whereas less progress was made by ICD patients (18% vs. 27%). This larger study does not confirm previous findings in a small study, where relative increases in aerobic power were comparable in patients with ($n = 8$) and without ($n = 16$) ICD.[14] The present results thus indicate some limitation to improve exercise performance in ICD patients despite the similar training dosage as other cardiac patients. This difference in trainability of exercise performance in patients with ICD may partially be explained by the greater percentage of patients with lower LVEF in the ICD group.

Myocardial ischaemia during exercise can induce life-threatening arrhythmias in any patient[19,20], but patients with a history of arrhythmias or cardiac arrest, such as ICD patients, are at a particularly higher risk during exercise.[6,7,11] In this study, ventricular premature beats in couplets, triplets or runs during exercise testing were observed more frequently in patients with ICD than in controls. Furthermore, there were appropriate ICD interventions for ventricular tachycardia during exercise in 5 patients, of whom 3 discontinued the rehabilitation programme and were excluded from the present analysis. One clinical study previously reported appropriate interventions for ventricular tachycardia during exercise in 2 patients.[14]

Between training sessions appropriate discharges occurred in 7 patients in this study, of which one occurred in a patient who later dropped-out of the rehabilitation programme and was therefore excluded from the study. Another clinical study reported only 2 discharges and one anti-tachycardia pacing in between sessions.[12] The present study, however, contained a larger cohort of patients in reference to earlier studies[12,14], therefore the incidence of ICD discharges, especially in between training sessions, was somewhat higher.

Finally, inappropriate ICD discharges in the event of supra-ventricular tachyarrhythmias are a well-recognised risk[21–25], which have been described to induce life-threatening ventricular tachyarrhythmias in some individuals.[26–28] In the present study, however, only one inappropriate ICD shock without pro-arrhythmic effect was delivered to a patient in sinus tachycardia during exercise training and none in between sessions. No other clinical studies reported inappropriate discharges during or in between exercise.[12,14] Although inappropriate therapies during exercise thus seem scarce and did not result in major complications, the possibility should not be ruled out.

One could criticise the present study regarding the patient population, since the ICD group consisted of patients referred to different rehabilitation programmes (Leiden/Leuven). However, the procedures for exercise testing and training were comparable. Both used cycle ergometer testing with similar equipment and protocols. The comprehensive rehabilitation programmes each consisted of similar exercise training components and information sessions.

In conclusion, the results of this study demonstrate that cardiac rehabilitation with exercise training is feasible and produces favourable results in ICD patients. Patients with an ICD can safely participate in an exercise training programme where careful supervision by qualified staff and constant vigilance during exercise activities are strongly recommended. There is evidence that the effect of training is somewhat lower than in control patients. Therefore, a randomised control study with evaluation of the physical as well as the psychosocial effects is warranted.

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