

Review Article

Exercise Training in Adults with Complex Congenital Heart Disease

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Abstract

In heart failure related to acquired heart disease exercise training represents an established treatment option. In contrast in congenital heart disease the value of exercise training is less clear. There is even concern that in patients with complex congenital lesions exercise training might be potentially harmful. Currently there are few studies including three randomized trials that evaluated the safety and benefit of exercise training in adults with complex congenital heart disease such as Fontan circulation, systemic morphological right ventricles, Fallot and Eisenmenger Syndrome. Cumulative data suggest that individualized low to moderate exercise training is safe in clinically stable patients. As in acquired heart disease it improves exercise capacity and heart failure symptoms. In contrast to patients with acquired heart disease exercise training is barely associated with increased quality of life. As documented by high numbers of dropouts and lacking long-term compliance the implementation of regular physical activity is difficult. It requires lifestyle changes through behavior modification which is challenging for physicians and patients. Implementation of regular physical activity requires life-long individualized counseling which should already begin in childhood.

ABBREVIATIONS

ACHD: Adult Congenital Heart Disease; ET: Exercise Training; HF: Heart Failure; HFNONACHD: Heart Failure Due To Non-Congenital Heart Disease; Peak v_{O_2} : Peak Oxygen Uptake. CMR: Cardiac Magnetic Resonance Imaging.

INTRODUCTION

In acquired heart disease with chronic stable HF symptoms current guidelines recommend ET as part of the non-pharmacological treatment (class I). It is well documented that ET does not adversely affect left ventricular remodeling, moreover it improves exercise capacity and quality of life and it even may reduce hospitalization and death [1,2].

In contrast in congenital heart disease the particular value of ET is less clear. Currently summarizing all published training studies less than thousand participants are included [3-11]. Most studies predominantly enrolled children with a great variety of heart defects ranging from minor cardiac lesions to complex disease with a unique hemodynamic situation presumably prone to develop exercise related ventricular damage. In addition most studies focused on the feasibility of exercise training in congenital heart disease. In contrast randomized studies are scarce.

At present even in complex congenital heart disease most

patients survive to adulthood, however dependent on the underlying defect already young adults are faced to an increasing incidence of HF, arrhythmias and death. A particular high risk group consists of young adults with a Fontan circulation, systemic morphological right ventricles after atrial redirection surgery, Fallot repair or with Eisenmenger Syndrome [12-14]. Recent training studies evaluated the safety and benefit of ET in this particular high risk groups [4-10]. The results of these studies are summarized to assess the safety and beneficial effect of ET in complex congenital heart disease.

Hemodynamic concerns

A great variety of congenital heart defect is associated with right heart disease potentially adversely affecting exercise related increase in cardiac output. Physiologically right heart function ensures increasing pulmonary blood flow and left ventricular preload which is essential to adopt stroke volume, cardiac output and oxygen uptake to the demands of exercise. Late after Fallot repair right ventricular impairment as well as significant pulmonary stenosis or regurgitation may result in diminished pulmonary blood flow. The Fontan circulation is characterized by the absence of a sub pulmonary ventricle. In this setting pulmonary blood flow depends on raised central venous pressure, skeletal muscle pump, inspiration and on low

pulmonary vascular resistance, which even under optimal Fontan conditions cannot provide an increase in cardiac output capable to supply the metabolic demands of exercise.

After atrial redirection surgery rigid baffles contribute to a lacking increase in cardiac output potentially leading to exercise dependent ischemia with a subsequent risk of arrhythmias and fibrosis promoting declining ventricular function. In Eisenmenger Syndrome intracardiac communications together with an inappropriate increase in systemic blood pressure result in an augmented right to left shunting amplifying cyanosis. Moreover there is a theoretical increased risk of potential fatal vagal reactions.

Patient selection

All studies included young adults with complex congenital heart defects who were in a stable hemodynamic condition, presenting in NYHA class I-III. Patients with arrhythmias at the time of evaluation or changes in medication within the last 3-6 months were excluded [4-11]. There were three randomized trials. One trial included Fallot patients [4]. Two studies enrolled patients with systemic morphological right ventricles, one of them exclusively patients after atrial redirection surgery [7,10]. In Eisenmenger Syndrome one case controlled study included a variety of complex congenital lesions [6] whereas the other trial only included patients with ventricular or atrial septal defects [9] Table 1.

Training program

There was a great variety regarding study design. ET was administered 10-24 weeks. Three randomized studies applied aerobic exercise training contributing to 50-70% of maximum exercise capacity over 20-60 minutes 3-5 times/week [4,7,10]. One study provided institutionalized supervised ET, the two others home based ET. One study encouraged patients to increase daily physical activity, participants were supplied with an accelerometer [5]. In pulmonary hypertension Becker-Grünig et al. started a three weeks in-hospital rehabilitation program with a combination of low resistance training und cycling [9]. The total daily 1.5 hour training time at 7 days/week was divided into several smaller units. If necessary patients received oxygen supply. The initial period was followed by a 12 weeks home

based program including 30 minutes bicycle training 5 days/week. Martínez-Quintana et al. also introduced a combination of low resistance training and cycling [6]. Over a period of 12 weeks the 2 weekly training units were supervised. Cordina et al. performed a 20 week resistance training in Fallot-patients followed by a detraining period over 12 week [8] Table 1

Effect of exercise training

As a common finding none of the studies reported adverse events. CMR studies in Fontan circulation and after atrial redirection surgery could not demonstrate ET related ventricular damage [8,10,11]. Moreover our study showed a positive effect on diastolic dysfunction [10]. Improved maximum exercise capacity was found independently from the chosen study design in all [4-7,9,10] except one study including a small number of patients with pulmonary hypertension [6]. Improved exercise capacity was expressed as a significant increase in maximum Watt [5,8,10], improved PaekVO₂ in five [4,7-10] and maximum exercise time in two studies [9,10]. These two studies also reported an improved NYHA-class [9,10] Table2.

One study reported a significant decline in maximum blood pressure [7]. Evaluation of muscle metabolism demonstrated rightward shift of the lactate curve in patients after atrial redirection surgery [10] (Figure 1)

Quality of life measurements were not influenced by training except in one study [9]. Dropout rate varied between 5.9 to 33.3%. A study with a 16.7% dropout rate reported reasons for withdrawal, which were job-related in five and personal reasons in three patients. Detraining resulted in declining exercise capacity [8]. Participants of one study were offered to keep the ergometer for another 6 months. Only half of the patients continued training resulting in improved exercise capacity, whereas detraining reduced exercise performance [10] Figure 2.

One study including patients with a systemic morphological right ventricle reevaluated participants three years after initial inclusion [7,23]. Short-term beneficial effects of exercise training did not persist. However, the training group revealed significantly higher PeakVO₂ and a longer event-free survival. The authors suggested that the favorable outcome could be interpreted as an inclining interest in sports participation [24].

Table 1: Patient population of the training studies. The numbers (N) of patients included in the table represent patients who finished the study.

Author (year)	Disease	N Int/con ^b	Time of intervention	Age (years) ^c	NYHA class ^c	Safety parameter	Dropout rate (%)
Therrien [4]	Fallot	9/8	12 weeks	35.9	-	Echocardiography	5.9
Winter [7]	D-Transposition atrial switch ccTGA ^a	24/22	12 weeks	32.6	1.3	Echocardiography NT-proBNP	15.4
Westhoff-Bleck [10]	D-Transposition atrial switch	21/19	24 weeks	29.3	1.4	CMR ^d Echocardiography NT-proBNP	16.7
Dua [5]	Miscellaneous	50	24 weeks	25.7	1.8	—	18
Cordina [8]	Fontan	6/5	20 weeks	32	1.5	CMR ^d	33.3
Martinez-Quintana [6]	Eisenmenger Syndrome	4/4	12 weeks	27.7	2.7	Saturation NT-proBNP	0
Becker-Grünig [9]	Eisenmenger Syndrome	15	15 weeks	48	2.7	NT-proBNP	25

Abbreviations: ^acongenital corrected transposition, ^bintervention /control, ^cmean, -no information available, ^dardiac magnetic resonance imaging.

Table 2: Observed training effects.

Author (year)	Adverse events	Exercise capacity	Training effect PeakVO ₂ ^a	Exercise duration	NYHA Class	Blood pressure	Quality of life
Therrien(2003) [4]	—	+	3.2 ml/kg/min	—	—	—	—
Winter [7]	—	+	3.4 ml/kg/min	—	—	+	—
Westhoff-Bleck [14]	—	+	3.8 ml/kg/min	+	+	—	—
Dua [5]	—	+	—	—	—	—	—
Cordina [8]	—	+	183 ml/min	—	—	—	—
Martinez-Quintana [6]	—	—	—	—	—	—	NT
Becker-Grünig [9]	—	+	1ml/kg/min	+	+	—	+

Abbreviations: No effect: —, Improved:+, ^a Change in Peak oxygen uptake, NT: not tested.

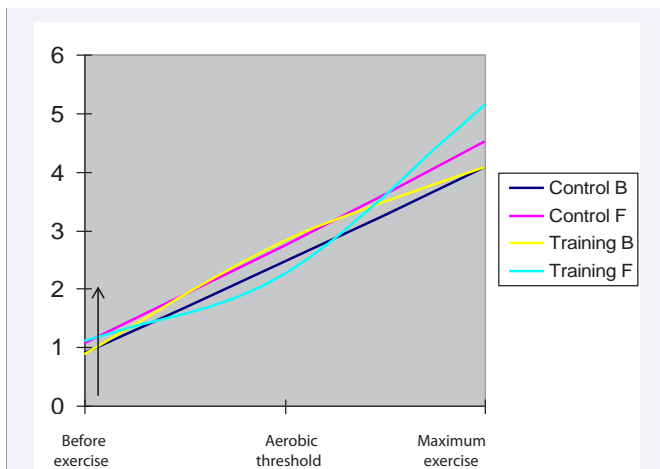


Figure 1 Lactate measurements during cardiorespiratory exercise testing in controls (n=20) and patients participating in ET (n=16) at baseline (B) and follow-up (F). (Based on results of Westhoff-Bleck et al [10]).

DISCUSSION AND CONCLUSION

In ACHD poor exercise capacity identifies patients at risk for hospitalization or death [15]. In HFnonACHD ET has been shown to be effective in improving exercise capacity as well as quality of life. Thus intervention to increase physical activity levels may be a desirable and beneficial strategy in complex ACHD.

At present few ET studies including three randomized trials evaluated patients with complex ACHD. The involved patients belong to the groups with the worst prognosis in this heterogeneous patient population [3-11,12-14]. Provided that patients are in a clinically stable condition low-to moderate aerobic ET or low resistance training can be performed safely in NYHA-class I-III [3-11]. Despite serious concern regarding potentially harmful effects of physical activity none of the studies reported adverse events such as exercise related arrhythmias, heart failure or death [3-11]. There is some evidence that frequent exercise participation might have a positive impact on long-term outcome [24]. Thus as in HFnonACHD individualized ET can be recommended in carefully evaluated patients [1,2].

Almost all studies demonstrated improvement of exercise capacity as it has been shown in HFnonACHD [3-10]. However, only two studies introducing individualized training programs

lasting longer than 15 weeks also reported improved NYHA-class [9,10]. These observations are in accordance with findings in training studies in HFnonACHD demonstrating that intensive and prolonged ET renders possible morphological and metabolic skeletal muscle changes which in turn allow extended physical activity [16-18]. Improved muscle metabolism could be demonstrated by a rightward shift in lactate curve in patients after atrial redirection surgery [10]. In addition this study evidenced a training effect on diastolic function, as it has been reported in HFnonACHD [10,19].

In contrast to HFnonACHD there is little evidence that ET improves quality of life [4-8,10,23]. Studies in ACHD demonstrate a lacking correlation between daily physical activity and quality of life except for those participating in competitive sports pointing to life-long physical activity [20,21,24]. In the past many patients with congenital heart defects were advised to restrain from physical activities. Consequently many patients are not adapted to regular physical activities being associated with lower confidence in performing ET [22,23]. In addition young adults stick in the rush-hour of life. They are faced to other time consuming daily demands as career and family [10]. All these factors contribute to high dropout rates and lacking long-term compliance. Regular participation in physical training requires lifestyle changes through behavior modification. Fun in physical

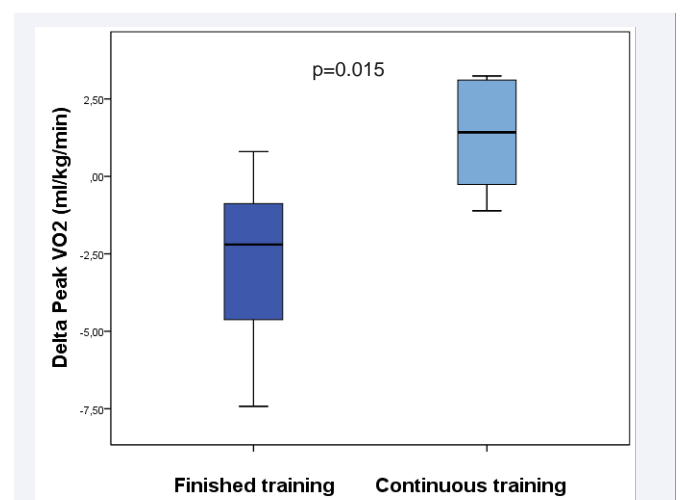


Figure 2 Impact of continuous training on PeakVO₂ after 6 months. (Based on results of Westhoff-Bleck et al [10]).

activities will improve willingness, however not all kinds of sports are suitable in ACHD. Both proper selection of suitable physical activities as well as motivation towards lifestyle modification remain challenging for physicians and patients.

In summary there is evidence that even in complex congenital heart disease mild to moderate aerobic and low-resistance ET can be performed safely in clinically stable patients NYHA-class I-III. ET improves exercise capacity and heart failure symptoms. In contrast participation in competitive sports is not advisable. Considering the increasing incidence of arrhythmias, heart failure and death in complex ACHD regular check-ups are essential to optimize treatment strategies including ET. Individualized life-long counselling already beginning in childhood could assist to achieve a positive attitude towards physical activity and lifestyle modification potentially influencing quality of life.

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