Cardiovascular Effect of Varying Interval Training Frequency in Rehabilitation of Severely Burned Children

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Structured exercise programs initiated after acute hospitalization can improve muscle strength and mass, cardiorespiratory capacity, and quality of life in severely burned children. In this retrospective study, we compared the cardiovascular effects of an exercise program incorporating a large number of interval training sessions with a traditional exercise program incorporating a small number of interval training sessions. Severely burned children who completed a large number of sessions (at least three sessions per week, $N = 40$) were matched to those completing a small number of sessions (a maximum of two sessions per week, $N = 40$). Maximal oxygen consumption ($\text{VO}_2 \text{ max}$) was measured via the modified Bruce treadmill protocol at discharge, on completion of the exercise program, and at follow-up visits at 6, 12, and 24 months postburn. Both groups were comparable in age (large 13.5 ± 3.0 years vs small 13.1 ± 3.3 years) and percent total BSA burned (large $50.8 \pm 14.8\%$ vs small $49.2 \pm 13.3\%$). For both groups, $\text{VO}_2 \text{ max}$ increased from discharge (large $22.6 \pm 3.8 \text{ ml/kg/min}$; small $22.6 \pm 5.0 \text{ ml/kg/min}$) to postexercise (large $29.5 \pm 6.0 \text{ ml/kg/min}$; small $28.0 \pm 5.8 \text{ ml/kg/min}$), 6 months (large $33.2 \pm 5.9 \text{ ml/kg/min}$; small $29.6 \pm 7.0 \text{ ml/kg/min}$), 12 months (large $35.0 \pm 7.5 \text{ ml/kg/min}$; small $31.7 \pm 7.1 \text{ ml/kg/min}$), and 24 months (large $37.0 \pm 7.2 \text{ ml/kg/min}$; small $32.4 \pm 9.2 \text{ ml/kg/min}$, $P < .001$). VO_2 increased to a greater extent with a large number of interval sessions than with a small number at 6 and 24 months (both $P = .021$). These findings suggest that a large number of interval training sessions impart a greater benefit on cardiorespiratory fitness than a small number of sessions.

Severe burn injuries are associated with an intense hypermetabolic response involving multiple organ systems.^{1,2} Because mortality from burn injuries has decreased significantly over recent decades, rehabilitation³⁻⁵ and strategies to improve the quality of life of burn patients have become more important.⁶

Children with severe burns can experience a significant decrease in cardiorespiratory fitness for up to 2 years postinjury.⁷ Of concern, reduced cardiorespiratory fitness and muscle endurance are strong predictors of poor future health in both burn patients and the general population.^{8,9} Burn patients benefit greatly from structured exercise programs that are initiated after discharge and that incorporate exercises to improve muscle strength and cardiovascular fitness.¹⁰⁻¹² However, the most effective exercise intervention for improving cardiovascular and muscle function in burn patients remains to be determined.

In young healthy subjects,¹³ patients with cardiovascular diseases,¹⁴ and individuals with type 2 diabetes mellitus,¹⁵ interval training has been shown to be superior to moderate continuous (noninterval) training at improving cardiorespiratory capacity. Whether the same is true for patients recovering from massive burns is unknown. This study was undertaken in severely burned children to compare the beneficial cardiovascular effects of an interval training program incorporating a large number of sessions with a traditional exercise program incorporating a rather small number of interval training sessions.

METHODS

Pediatric burn patients who underwent acute treatment at our institution between 2006 and 2015 and received interval training during the rehabilitation program after their acute stay were included in this retrospective study. At our institution, patients over the age of 7 years are offered an occupational and physical therapy program after discharge. We identified patients who completed a large or small number of interval training sessions and matched patients in these groups with regard to age, sex, and percent TBSA. Cardiovascular fitness, as assessed by maximal oxygen consumption ($\text{VO}_2 \text{ max}$), was determined at discharge, on completion of the exercise program (postexercise), and at follow-up visits at 6, 12, and 24 months postburn. The study was reviewed and approved by the local Institutional Review Board (Protocol 04-157). Informed consent and/or the children's assent were obtained from all individual participants and/or their parents or legal guardian.

Exercise Training

Each subject participated in a structured rehabilitation program that consisted of a 6- or 12-week exercise program depending on TBSA burned (6 weeks: 30–59% TBSA burned

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and 12 weeks: >60% TBSA burned).¹⁰ Reasons for excluding patients from the exercise program were as follows: leg amputation, anoxic brain injury, psychological disorders, quadriplegia, or cognitive disorders. The training consisted of resistance and aerobic exercise up to 5 days per week and began immediately after discharge from the intensive care unit. Individual VO_2 max was determined before the first session. Each session included a warm-up and cool down period involving 10 minutes of gentle treadmill or cycle ergometer training at <50% of VO_2 max (60–70% of maximal heart rate). The decision of whether performing an interval training session was performed by the physical therapists and clinicians on safety and physical capability. Interval training was performed at 85 to 90% of peak heart rate using either a treadmill (1- or 2-minute intervals) or cycle ergometer (2-minute intervals) for 20 minutes. Each interval was separated by a 2-minute active pause, walking at 50–70% of maximal heart rate. The duration of the intervals and the total session was controlled with the treadmill or cycle ergometer. The sessions were stopped after 20 minutes, and the subjects continued with the cool down.

Patients completing a large number of interval training sessions participated in at least three sessions per week of aerobic interval training, whereas those completing a small number of interval training participated in a maximum of two interval training sessions per week. On days when not performing interval training, the subjects trained at 70–75% of their maximal heart rate for 30–35 minutes. Heart rate and oxygen saturation were continuously monitored during exercise.

Both groups also performed resistance exercise training at least three times weekly alternately using bench, leg, and shoulder presses; leg extension; biceps, leg, and triceps curls; and toe raises. During the first week of training, the patients were shown proper weight lifting techniques and familiarized themselves with the different machines. The weight was set at 50–60% of the subjects for three-repetition maximum in the first week (three sets of 4–10 repetitions), increased to 70–75% in weeks 2–6 (three sets of 4–10 repetitions), and set to 80–85% in weeks 7–12 (three sets of 8–12 repetitions). Weights increased gradually as allowed by the subject's performance.

Measurement of VO_2 Max

VO_2 max was measured using the modified Bruce treadmill protocol and the Ultima CardiO2 metabolic cart (Medgraphics Cardiorespiratory Diagnostics, Saint Paul, MN).^{16,17} The system was calibrated before each use using a reference gas containing oxygen and carbon dioxide at a known concentration. During exercise testing, inspired and expired gas flow rate and volumes were measured with the aid of an airtight mouthpiece. The exercise test started at a speed of 2.7 km/h with 0% elevation, and these increased every 3 minutes (speed: 4.0, 5.4, 6.7, 8.0, and 8.8 km/h; elevation: 5, 10, 12, 14, and 16%). Patients were instructed to give maximum effort so that VO_2 max could be reached. The exercise test was stopped on volitional fatigue or when the patient was unwilling to continue. Resting VO_2 , resting heart rate, and maximal heart rate were also determined during the exercise testing protocol.

Statistical Analysis

Unless stated otherwise, the data are reported as mean $\pm$ SD. A *P* value of less than 0.05 was considered significant in all

statistical tests. Parametric data were analyzed using Student's *t*-test, paired *t*-test, or repeated-measures analysis of variance as appropriate. Nonparametric data were analyzed using Mann-Whitney U-test, and categorical data were analyzed using chi-square test. Statistical analyses were performed using GraphPad Prism for Windows 7.03 (GraphPad Software, La Jolla, CA).

RESULTS

A total of 128 patients who were admitted to our institution for burn injury and participated in a rehabilitation program after their acute stay were identified. Of these, 66 patients completed a large number and 62 a small number of interval training sessions. After removing patients with missing data and matching for age, sex, and percent TBSA burned, there were 40 patients per group. The age was 13.5 ± 3.0 years in the large number group and 13.1 ± 3.3 years in the small number group. Both groups were also well balanced with regard to sex and percent TBSA burned (Table 1). The predominant mechanism of injury in both groups was flame burn (62.5% for large vs 87.5% for small), followed by electrical injury (25.0% for large vs 7.5% for small) and scald injury (12.5% for large vs 5.0% for small, Table 1). All patients were participating concurrently in different randomized controlled trials. There was no significant difference between the two groups regarding the administration of study drugs (Table 1). The results of these trials have been reported elsewhere.^{18–20}

Exercise Testing

VO_2 max at discharge was comparable in the large number group (22.6 ± 3.8 ml/min/kg) and the small number group (22.6 ± 5.0 ml/min/kg, *P* = .976; Table 2). VO_2 max improved from discharge in both groups (*P* < .001, analysis of variance). Tukey's multiple comparison test detected significant differences in VO_2 max at all time points for both groups when compared with the time of discharge and the time of completion of the exercise program (*P* < .001 for all). VO_2 max was higher in the large number group than the small number group at 6 months (*P* = .021) and 24 months (*P* = .021), with a trend toward greater VO_2 max in large number group being seen at 12 months (*P* = .058). No difference in VO_2 max between groups was evident on completion of the exercise program (*P* = .265). In the large number group, percent change of VO_2 max from discharge was significantly higher at all time points examined when compared with the value obtained for postexercise (*P* < .001). Similar observations were seen in the small number group at 12 and 24 months (*P* < .01). Percent change of VO_2 max from discharge was not different between the two groups postexercise (*P* = .461) or 6 months after burn injury (*P* = .071) but was greater in the large number group at 12 months (*P* = .042) and 24 months (*P* = .034) postburn.

In the large number group, resting VO_2 was lower at the 24-month follow-up than at discharge (*P* = .025), but no differences were detected between discharge and the other time points. No significant differences in resting VO_2 were detected in the small number group. A comparison of resting VO_2 between groups revealed no differences at discharge (*P* = .552), postexercise (*P* = .438), 12 months (*P* = .530),

Table 1. Patient demographics

Characteristic*	Large Number of Interval Training Sessions	Small Number of Interval Training Sessions	P Value
Age at burn (yr)	13.5 ± 3.0	13.1 ± 3.3	.626
Sex, male, <i>n</i> (%)	34 (85.0)	30 (75.0)	.263
%TBSA burned	50.8 ± 14.8	49.2 ± 13.3	.614
%TBSA third	40.0 ± 23.0	40.4 ± 20.0	.933
Presence of inhalation injury, <i>n</i> (%)	11 (27.5)	14 (35.0)	.470
Length of hospital stay (d)	30.2 ± 18.0	28.8 ± 15.1	.727
Type of burn			.241
Flame, <i>n</i> (%)	25 (62.5)	35 (87.5)	
Scald, <i>n</i> (%)	10 (25.0)	3 (7.5)	
Electrical, <i>n</i> (%)	5 (12.5)	2 (5.0)	
Study drug			.976
Oxandrolone, <i>n</i> (%)	15 (37.5)	16 (40.0)	
Oxandrolone/propranolol, <i>n</i> (%)	10 (25.0)	7 (17.5)	
Propranolol, <i>n</i> (%)	8 (20.0)	9 (22.5)	
Growth hormone, <i>n</i> (%)	2 (5.0)	3 (7.5)	
Metformin, <i>n</i> (%)	2 (5.0)	2 (5.0)	
Control, <i>n</i> (%)	3 (7.5)	3 (7.5)	

*Data expressed as mean ± SD unless noted otherwise.

Table 2. Exercise testing of interval and continuous training group

Parameter*	Discharge	Postexercise	6 Mo	12 Mo	24 Mo
Large number of interval training sessions					
BMI (kg/m ²)	20.3 ± 3.5	21.0 ± 3.9	21.4 ± 5.4	22.3 ± 6.4	22.6 ± 6.6
VO ₂ rest (ml/min/kg)	6.2 ± 1.9	5.7 ± 1.7	6.4 ± 2.1 [§]	5.5 ± 2.1	5.1 ± 1.7**
VO ₂ max (ml/min/kg)	22.6 ± 3.8	29.5 ± 6.0**	33.2 ± 5.9** [§]	35.0 ± 7.5**	37.0 ± 7.2** [§]
VO ₂ max (% change) [†]	—	31.3 ± 21.2	48.1 ± 23.1**	56.4 ± 32.4** [§]	65.5 ± 33.1** [§]
HR rest (bpm)	110.2 ± 16.4	100.5 ± 16.4	92.8 ± 19.4	87.7 ± 13.8	85.1 ± 13.3
HR max (bpm)	164.8 ± 19.5	169.9 ± 22.3	174.0 ± 20.2	177.5 ± 17.4	184.3 ± 12.8** [§]
Small number interval training sessions					
BMI (kg/m ²)	21.3 ± 4.3	22.3 ± 7.8	22.0 ± 5.1	22.4 ± 5.5	24.0 ± 5.8
VO ₂ rest (ml/min/kg)	5.9 ± 2.4	6.1 ± 1.8	5.4 ± 1.7	5.8 ± 1.7	5.2 ± 1.6
VO ₂ max (ml/min/kg)	22.6 ± 5.0	28.0 ± 5.8**	29.6 ± 7.0**	31.7 ± 7.1**	32.4 ± 9.2**
VO ₂ max (% change) [†]	—	27.0 ± 28.6	34.8 ± 37.3	44.4 ± 34.9**	48.8 ± 34.0**
HR rest (bpm)	107.3 ± 17.6	98.3 ± 13.3	91.4 ± 12.3	83.8 ± 16.3	83.1 ± 16.7
HR max (bpm)	168.5 ± 22.9	176.4 ± 19.1	177.7 ± 22.6	175.8 ± 20.8	176.1 ± 18.9 [§]

BMI, body mass index; VO₂ rest, resting oxygen consumption; VO₂ max, maximal oxygen consumption; HR rest, resting heart rate; HR max, maximal heart rate; postexercise, immediately after completing the exercise program.

*Data expressed as mean ± SD.

[†]Expressed as percent change from discharge.***P* < .01 versus discharge.[§]*P* < .05 versus small number group.

or 24 months (*P* = .785). However, resting VO₂ was lower in the small number group at 6 months postburn (*P* = .027, Table 2).

Maximal heart rate was comparable in both groups at discharge (*P* = .461), postexercise (*P* = .184), 6 months (*P* = .465), and 12 months (*P* = .715) but was higher in the large number group at 24 months (*P* = .033, Table 2). Maximal heart rate increased over time in the large number group (*P* < .001), but not in the small number group (*P* = .206).

Resting heart rate was comparable between both groups at discharge (*P* = .473), postexercise (*P* = .526), 6 months (*P* = .721), 12 months (*P* = .276), and 24 months (*P* = .589).

However, resting heart rate decreased over time in both groups (both *P* < .001).

DISCUSSION

Severe burn injury substantially affects cardiopulmonary function, contributing to fatigue and a poor quality of life. The present study confirms that cardiorespiratory capacity increases significantly in severely burned children during an in-hospital exercise program. Moreover, it shows for the first time that more frequent use of interval training in a rehabilitative exercise program for pediatric burn patients results in superior increases in VO₂ max, a key measure of

cardiopulmonary fitness in both clinical and research settings. Notably, the improvements seen with interval training persisted for several months after completion of the exercise program, highlighting the long-lasting benefits of incorporating interval training into rehabilitative exercise programs for pediatric burn patients.

In the present study, severely burned children in both groups benefited from a rehabilitation program in terms of cardiorespiratory capacity. In agreement with our previous findings,²¹ VO_2 max significantly increased immediately after the rehabilitation program and continued to increase throughout the 24-month follow-up period. Nevertheless, several studies have shown that cardiorespiratory capacity and strength in severely burned children remain below levels seen in nonburned children for 3 years postburn.^{12,22}

Patients who performed three to five sessions per week of aerobic interval training showed a greater increase in absolute VO_2 max and percent change in VO_2 max than patients who performed a fewer number of interval training sessions (maximum of two interval training sessions per week). Even greater differences were seen at long-term follow-up (12 and 24 months). In a study of healthy prepubertal children, Baquet et al showed that both interval and moderate continuous training could increase cardiorespiratory capacity. They also pointed out that interval is more fun for children than monotonous moderate training,²³ an important factor when trying to engage children in exercise programs and encouraging them to continue exercising on their own. Studies conducted in patients with metabolic syndrome and in those participating in cardiac rehabilitation programs after myocardial infarction or chronic heart failure have shown that aerobic interval training is associated with a greater increase in VO_2 peak than moderate continuous training.^{24–26} The findings of the present study are consistent with these previous reports and suggest that interval training is superior to moderate continuous training. We recommend that rehabilitation programs in severely burned children include a mixture of both interval and moderate continuous training, with this being tailored depending on the patients' physical and mental status as well as to ensure safety during exercise. Of great importance is the patient's interest because compliance in exercise programs as well as the continuation of exercise after these programs have concluded is essential for the patient's rehabilitation.²⁷

Limitations

One limitation of the present study was that both groups received (at least a small number of) interval training sessions. Nevertheless, the group with a larger number showed a greater increase in VO_2 max. Furthermore, it is not known to what extent and in what ways the patients performed exercise training after their in-hospital rehabilitation program and how this could have influenced the assessments of cardiorespiratory capacity. However, all patients are strongly encouraged to stay active after the exercise program to further improve their cardiorespiratory fitness. In addition, we did not include a group of patients not participating in exercise training or a nonburned control group completing an exercise program at our institution. However, we have shown in previous studies that exercise programs are superior to no exercise in terms of improving muscle strength, muscle mass, and cardiorespiratory

capacity.²⁸ Because this was not a randomized controlled trial, further studies are necessary to evaluate possible differences in interval training with varying frequency of sessions and between interval and moderate training in general.

CONCLUSION

Both a larger number and smaller number of interval training sessions combined with continuous training significantly increase cardiorespiratory capacity in severely burned children up to 24 months postinjury. A larger number of interval training sessions may be superior to a small number of interval training sessions, and this should be evaluated more in depth. An adequate combination of intensity, stimulation, and duration of exercise should be offered to children as applicable to alleviate potential issues of boredom.

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