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Cardiorespiratory Capacity and Strength Remain Attenuated in Severely Burned Children at Over 3 Years Postburn

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Abstract

Objectives—To compare physical capacity and body composition between burned children at approximately 4 years postburn and healthy fit children.

Study design—In this retrospective case-control study, we analyzed strength, aerobic capacity, and body composition of severely burned children (n=40) at discharge, after completion of a 6 to 12-week rehabilitative exercise training program, and at 3 to 4 years postburn. Values were expressed as a relative percentage of those in sex/age-matched children for comparison (n=40 for discharge and post exercise; n=40 for 3.5 years postburn).

Results—At discharge, lean body mass (LBM) was 89% of that in non-burned children, and exercise rehabilitation restored this to 94% ($P < .01$). At 3.5 years postburn, LBM (94%), bone mineral content (89%), and bone mineral density (93%; each $p = 0.02$) remained reduced, while total body fat was increased (148%, $p = 0.01$). Cardiorespiratory fitness remained lower in burned children both after exercise training (75%; $p < 0.0001$) and 3.5 years later (87%; $p < 0.001$). Peak torque (60%; $p < 0.0001$) and average power output (58%; $p < 0.0001$) were lower after discharge.

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Although exercise training improved these, they failed to reach non-burned levels (83–84%; $p<0.0001$) but were maintained at 85% and 82%, respectively, 3.5 years later ($p<0.0001$).

Conclusions—Although the benefits of rehabilitative exercise training on strength and cardiorespiratory capacity are maintained at almost 4 years postburn, they are not fully restored to the levels of healthy children. Although the underlying mechanism of this phenomenon remains elusive, these findings suggest that future development of continuous exercise rehabilitation interventions after discharge may further narrow the gap in relation to healthy adolescents.

Keywords

Body composition; exercise program; muscle strength; peak aerobic capacity; rehabilitation; standard of care

Over the past decades, advances in modern burn care have improved the survival rate, particularly in children (1). However, this progress has presented new challenges in the long-term treatment and rehabilitation of burn survivors. Patients experience complications associated with hypermetabolism during the acute postburn period as well as physical deconditioning. This deconditioning is exacerbated by immobilization in the intensive care unit (2) and by the systemic response to thermal injury, which is characterized by a dramatic metabolic shift to a catabolic state (3,4). This results in a pronounced loss of lean body mass, weakness, and fatigability (5).

The pathologic processes responsible for physical deconditioning persist well after discharge. Jeschke et al showed that basal metabolism (measured as resting energy expenditure) continues to be significantly elevated in pediatric burn patients compared with age-matched controls for up to 2 years postburn (6). Similarly, Hart et al found that rates of muscle breakdown also remain above normal more than a year after the injury (7). Persistent catabolism is particularly concerning in pediatric patients, as they are in an important period of development and growth. A longitudinal study performed in 1990 showed that pediatric burn survivors experience a precipitous decline in growth velocity and that it takes, on average, 3 years for patients to return to age-appropriate growth velocities (8). Since this finding, a wide range of interventions have been investigated to mitigate catabolism and deconditioning associated with severe burns. Early surgical excision, aggressive nutrition support, and a variety of pharmacologic therapies (such as growth hormone, oxandrolone, and propranolol) have been found to be effective in modulating the metabolic response and improving outcomes during the acute phase (9–13). In addition, structured rehabilitative exercise programs following the acute phase, along with anabolic therapy, are important for improving burn recovery (14–17).

Although significant improvements in short-term outcomes have been well documented with modern burn care and rehabilitative exercise programs, the lasting effects of these (beyond 2 years) are unknown. To determine if rehabilitation programs are needed beyond 2 years postburn, we compared physical capacity and body composition in severely burned children at up to 3.5 years postburn with those in healthy age- and sex-matched non-burned children.

Materials and Methods

This was a retrospective case control study with controls matched by age and sex. Upon admission to our institution, pediatric patients underwent standard of care treatment involving reconstructive surgery and skin grafting. They were then discharged once wounds were 95% healed. Patients returned for follow-up at 6, 9, 12, and 24 months after discharge and yearly thereafter for further reconstructive surgery and continued care. The study analysis was performed on a large set of data from previous and ongoing studies (approved by the Institutional Review Board [IRB 04-157]). At discharge, patients provided consent and underwent testing for body composition, exercise strength, and aerobic capacity. They then completed a 6- to 12-week aerobic and resistance exercise rehabilitation training program. Following the rehabilitation training, they again underwent testing for body composition, exercise strength, and aerobic exercise. As noted, patients return to our institution yearly for ongoing assessment. For this study, we examined changes in these measures of body composition, exercise strength, and aerobic capacity in the same patients beginning from discharge until after the exercise rehabilitation program and until 3 to 4 years postburn compared with healthy controls.

Study subjects

This retrospective case-control study was approved by the Institutional Review Board (IRB 04-157 and IRB 01-106) at University of Texas Medical Branch. Study patients were admitted to our institution between August 2005 and January 2014, and the presented data were collected from September 2005 to January 2017. All patients met the following inclusion criteria: >7 years of age, >30% total burned surface area, and participation in our rehabilitative exercise training program (6 or 12 weeks). Exclusion criteria included non-thermal injuries and any amputations of the extremities. All enrolled patients underwent body composition, strength, and aerobic capacity testing at discharge, after completion of the rehabilitation program, and at 36 to 48 months postburn. To control for sex as well as growth and development over 3.5 years, we matched each burned child by age and sex to two separate controls: one for the discharge and post exercise training time points (n=40) and a different control subject for the 3- to 4-year postburn time point (n=40). Please see Figure 1 for study design. Healthy-fit subjects were recruited from the local community through publically posted flyers and word of mouth. Data were collected from these volunteers (n = 80) at a single time point. To be considered healthy-fit, subjects must have had a peak oxygen consumption (VO_2) of at least $38 \text{ mL O}_2 \cdot \text{kg}^{-1} \text{ min}^{-1}$. Additionally, all control subjects were considered fair-to-excellent (male: $38\text{--}45 \text{ mL O}_2 \cdot \text{kg}^{-1} \text{ min}^{-1}$; female: $39\text{--}42 \text{ mL O}_2 \cdot \text{kg}^{-1} \text{ min}^{-1}$) according to norms for children aged 13 to 19 years reported by the Cooper Institute for Aerobics Research (18). Each healthy-fit child was matched to each burn patient for sex and age. For all study patients and control subjects, informed consent was obtained from parents or legal guardians and child assent was obtained, as applicable, before participation in the study.

Rehabilitative exercise program

The rehabilitation program that is now the standard of care at our institution has been described in detail elsewhere (5). Briefly, patients participated in a 6- or 12-week training

program based on their total body surface area burned (6 weeks for > 30–59% and 12 weeks for > 60%). The training program consisted of alternating days of resistance and aerobic exercise sessions, which took place up to 5 days per week under the supervision of a trained exercise specialist. Exercise training was initiated immediately after discharge once wounds were at least 95% healed. The aerobic component of the rehabilitation program involved at least 3 to 5 aerobic training sessions a week with a treadmill or cycle ergometer for 10 to 40 minutes a day at an intensity of 50–85% of heart rate reserve. The strength training program involved at least 3 weekly sessions of 8 basic resistance exercises: bench, leg, and shoulder presses; leg extension; biceps, leg, and triceps curls; and toe raises. All exercises were performed using variable resistance machines or free weights. More severe burns and skin grafting would limit mobility and the ability to exercise on the treadmill or cycle ergometer. On typical days, an aerobic warmup of 10 minutes would start the main exercise session and a cool down would end the session. During the first week of training, the patients were familiarized with the exercises and equipment, and they were instructed on proper technique with minimal weights/loads. Weights/loads were then gradually increased over time from 50 to 60% of the patient's 3-repetition maximum to a goal of 80 to 85% of the 3-repetition maximum by week 6.

Bone mineral content (BMC), bone mineral density (BMD), total body mass, total body fat, and total lean body mass (LBM) were determined using dual-energy X-ray absorptiometry (Hologic model QDR-4500-W, Hologic, Inc., Marlborough, MA, USA) and analyzed with dedicated software (19). The machine was calibrated daily using a phantom. Scans were performed with the individual completely motionless; otherwise, they were repeated.

Aerobic capacity was assessed by measuring peak VO_2 during a standardized treadmill exercise test using the modified Bruce protocol with ongoing heart rate and oxygen saturation monitoring. VO_2 was quantified using a combined VO_2/CG exercise system (Medgraphics Cardio O_2 , St. Paul, Minnesota) with continuous breath-by-breath analysis of inspired and expired gas composition, flow, and volume. O_2 and CO_2 gas and air flow were calibrated using known gasses and a 3-L syringe prior to each test. Subjects were continually encouraged to complete 3-minute stages, and the test was ended once peak volitional effort was achieved. In all cases, the test was considered maximal upon volitional fatigue (subjects signaled to stop exercise) and at least one of the following criteria were met: a respiratory exchange ratio > 1.05 , a leveling off in VO_2 with increasing workloads ($< 2 \text{ mL O}_2 \cdot \text{kg}^{-1} \text{ min}^{-1}$), or exercise heart rate > 190 beats/min. Further details on the methodology for indirect calorimetry has been published by our group (20).

Strength was assessed via isokinetic dynamometry. Peak torque and average power generated with a 150° extension of the knee joint on the dominant leg were measured using a Biodex System 3 dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA) (21).

Statistical analyses

Subjects' physical and exercise characteristics for each time point were analyzed using a 1-way repeated measures ANOVA with Bonferroni adjustment post hoc for multiple comparisons. Each burned child was matched to a non-burned child based on age and sex. To determine absolute differences between burned children and age- and sex-matched non-

burned children, we performed a 1-way ANOVA with Holm-Sidak multiple comparison post hoc tests. To control for the effects of growth and development, we expressed values as a relative percentage of those in the age- and sex-matched counterpart and performed comparisons using a one-way repeated measures ANOVA with Bonferroni post hoc tests and appropriate p value adjustments per group comparison (p values = $0.05 \div 4$ group comparison = $p < 0.013$). Data were analyzed and figures generated using GraphPad Prism (Version 6.0, La Jolla, California), with significance set at $p < 0.05$. All data are reported as mean $\pm$ standard deviation.

Results

Demographics of the burn patients and control groups are summarized in the Table. The predominant mechanism of injury was flame burn (33/40; 83%), followed by electrical injury (4/40; 10%) and scald injury (3/40; 7%). Patients remained in the intensive care unit for 27 ± 17 days and participated in a rehabilitative exercise program for 8 ± 2 weeks. All patients were concurrently participating in other clinical trials evaluating drug therapies for burns. Eleven (27%) received propranolol, 10 (25%) received a combination of oxandrolone and propranolol, 4 (10%) received growth hormone, 4 (10%) received metformin, and 1 (3%) received ketoconazole. The remaining 10 (25%) received no study drug. The results from these drug studies have been previously reported, including participants included in the current manuscript (9,12,13). Long-term follow-up testing was performed at 3.5 ± 0.5 years postburn. At discharge, burned children were in the very poor-to-poor category (male: <35 mL O₂ kg⁻¹ min⁻¹; female: <25 mL O₂ kg⁻¹ min⁻¹), and non-burned children were in the good category ($<$ male: 45.2–50.9 mL O₂ kg⁻¹ min⁻¹; female: 35–38.9 mL O₂ kg⁻¹ min⁻¹) (18). According to Eisenmann et al, the burned boys' and girls' values would fall below the 2nd percentile, and those of non-burned healthy children would be between the 50th and 75th percentile (22).

Of the body composition measures, total lean mass was the most affected by burn injury after the acute phase (ie, at discharge) at 89% of that in the age- and sex-matched control group. Exercise training partially restored lean mass, although it remained lower than that of control children (94%; $p < 0.01$). At 3.5 years postburn, total lean mass was significantly lower (94%; $p = 0.01$), as was BMC (89%, $p = 0.02$) and BMD (93%, $p = 0.01$). On the other hand, total body fat increased to 148% compared with the age- and sex-matched control group ($p = 0.01$).

As shown in the Table and Figure 2, relative peak VO₂ decreased at discharge relative to healthy controls (51%, or 57% when normalized to LBM; $p < 0.0001$). Exercise training partially restored peak VO₂ to control levels (70%, or 75% normalized to LBM; $p < 0.0001$). At 3.5 years postburn, peak VO₂ remained attenuated compared with values for age- and sex-matched controls (82%, or 87% normalized to LBM; $p < 0.001$). Peak heart rate was also lower in burn patients at discharge than in controls (89%, $p < 0.0001$), and exercise training improved this index of cardiac function to 94% ($p < 0.05$). At 3.5 years postburn, peak heart rate values remained lower than age- and sex-matched control values (94%, $p < 0.01$).

At discharge, burned children had reduced peak torque (53%, or 60% normalized to LBM; $p < 0.0001$) and average power output (52%, or 58% normalized to LBM; $p < 0.0001$) (Table and Figure 2). After exercise training, both peak torque and power output were improved, but remained lower than control values (Peak torque: 79%, or 83% LBM-normalized, $p < 0.0001$; Power: 80%, or 84% LBM-normalized, $p < 0.0001$). At 3.5 years postburn, the improvements in peak torque and power output seen after exercise training were maintained, although peak torque and power remained reduced compared with controls (79%, or 85% LBM-normalized, $p < 0.0001$; Power: 77%, or 82% LBM-normalized, $p < 0.0001$).

Discussion

This study builds on prior work by reporting long-term exercise capacity at 3.5 years postburn in response to an exercise program implemented when the patients were discharged from the burn intensive care unit. We show that participation in a 6- to 12-week exercise program after discharge significantly increases their exercise capacity. More importantly, our data show that strength and cardiorespiratory capacity at 3.5 years after burn injury are similar to those at completion of the rehabilitative exercise program. Nevertheless, these physical capacities remain lower than those in sex- and age-matched healthy children.

The relatively low LBM observed in the patients at discharge is in keeping with other reports of decreased lean mass in severely burned children (23,24). However, we found the LBM to be slightly higher, an effect that may be related to advances in nutritional and metabolic support during acute burn care that have been made in past years (25). Interestingly, differences in body composition between burned children and healthy children with comparable body mass index, age, and sex remain the same at 3.5 years after injury. However, this is not the case with total body fat, which continues to increase in burned children. This may be related to a reduction in physical activity in the years after injury, possibly due to posttraumatic depression (26,27). This inactivity may increase overall fat accumulation (principally central fat), which is typical after burns (28,29). This sedentary state is confirmed by statistically lower bone mineral content and bone mineral density at 3.5 years after injury, as it may elevate risk of bone fractures in these young patients. However, as shown by O'Halloran et al, this effect may also be related to the post-burn inflammatory response, and therefore, the change in bone density may be associated with the burn injury rather than solely reflecting lower activity (30).

As demonstrated by this and other studies by our group, exercise programs initiated immediately after discharge improve strength and cardiorespiratory capacity (5,14,15,20,21,31). Nevertheless, strength and cardiorespiratory capacity remained approximately 20% lower in burn patients than in healthy subjects at discharge. Furthermore, at 3.5 years postburn, peak VO_2 , peak torque, and average power, whether normalized to LBM or not, were still reduced. This suggests that severe burns induce a growth delay of approximately 3 to 4 years. Wurzer et al showed that exercise training after discharge has measurable benefits until 1 year postburn, with this effect tending to disappear at 2 years postburn (32).

Our results are consistent with these findings and showed that at 3.5 years postburn, well after exercise training had ceased, peak VO_2 increased. This increase coincides with the resolution of hypermetabolism as reported by Jeschke et al and the normal developmental growth of the heart and lungs (6). Importantly, Wurzer et al did not analyze differences between burned children and age- and sex-matched healthy, non-burned controls. Using this approach, we found that extension of exercise rehabilitation may be needed between 2 to 4 years postburn to approach a more complete restoration of physical capacities in children. Our results show that there is a gap of slightly less than 20% for cardiopulmonary capacity (peak VO_2) and slightly more than 20% for strength abilities (peak torque, average power). This gap is smaller at 3.5 years postburn than at completion of 6 to 12 weeks of exercise rehabilitation, and could be attributed to normal growth and development (non-normalized VO_2 from 70 to 82%; normalized LBM from 75 to 87%). However, these values were still 18% to 13% less than those of age- and sex-matched controls. It is suggested that, even though the hypermetabolic state persists for years after burn (27), most of the inflammatory and metabolic dysregulation ends at 3 years postburn (6). Thus, this improvement in metabolic health, in conjunction with normal growth and development, may have enhanced aerobic capacities. On the other hand, long-term (>5 years post burn) data assessing systemic sequelae of burn injury are still sparse. As recently suggested by Duke et al, one focus of future studies should be on cardiovascular dysfunction, which may impact aerobic capacity negatively (33). In contrast to aerobic capacity, strength did not differ from after exercise training until 3.5 years postburn, and it remained about 20% less than that in healthy non-burned children.

Exercise has been shown to improve psychological outcomes (34), an important finding given that most burn patients tend to become inactive and burn injury can be associated with depression. In this context, Pena et al have shown that exercise programs performed in the community have comparable results as those performed at specialized burn centers (35). Regular exercise programs may be useful in children who have sustained severe burns to fill the gap they have in relation to healthy children, as we have found that, after burns, early physical rehabilitation exercise that is started at discharge improves functional exercise capacity and lean body mass (5,14,15,20,21).

A limitation of this study was the inclusion of a small number of patients who were participating in randomized clinical trials investigating the effects of anabolic drugs and exercise. However, because we have previously found that anabolic drugs do not have a significantly greater effect on strength and cardiorespiratory capacities after 1 year than exercise alone, we do not believe this subsample affected our results (23,36). Additionally, we did not include a non-burned group completing the 6- to 12- week exercise training as a control; however, we have previously shown that including exercise in our hospital's standard of care is superior to standard of care alone in improving lean body mass, strength, and aerobic exercise capacity (5). Another limitation of this study was the small sample size, which is attributable to the majority of patients failing to return for very long follow-up visits over 2 years and thus being ineligible for study participation. Patients who return for long-term testing are more likely to have a positive view of exercise and fitness, possibly influencing their decision to return to the exercise center for the 3.5-year follow-up visit. Regardless, the cohort of patients returning for long-term follow-up testing may be skewed

towards a population with more long-term complications and with a greater inclination/motivation to maintain their relationship with the treating institution where this research was performed. Additionally, because drug interventions improve the hypermetabolic response in burn survivors, we cannot determine if the drugs given affected the results for this particular group of burned children. However, we have previously shown that oxandrolone in isolation or with oxandrolone both improve lean body mass, strength, and peak oxygen uptake (37). We have also found that propranolol administration does not impair muscle mass, strength, or VO₂ peak gained through an exercise program (36). Likewise, we recently found that propranolol administration did not affect the heart rate response to submaximal exercise, and therefore, subjects were able to maintain exercise intensity during the training sessions, as assessed using heart rate (38). Lastly, we analyzed children during puberty, and some of the enrolled patients may not have complete puberty before long-term testing.

In conclusion, our data show that severely burned children experience a significant decrease in strength and cardiorespiratory capacity at discharge, as seen through comparison with non-burned children; however, these are improved after completion of a 6- to 12-week physical rehabilitation program. At 3.5 years after discharge, patients still significantly differ from healthy age- and sex-matched non-burned children, underscoring the delay that they experience in growth and development into adulthood. Our data highlight the need for severely burned children to not only enroll in rehabilitative exercise programs after discharge, but also participate in regular physical activity during the ensuing years, until fully developed. Further research is needed to more fully understand the factors underlying this gap between severely burned and healthy children with the goal of minimizing it.

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Abbreviations

LBM	lean body mass
VO₂	oxygen consumption

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Figure 1.
Patient flow diagram. IRB: Institution review board; TBSA: total body surface area.

Figure 2.

Cardiorespiratory fitness, as reflected by **A**, peak VO₂, and strength, as reflected by **B**, peak torque and **C**, average power. All are provided as non-normalized and LBM-normalized values. A/S matched, age- and sex-matched non-burned controls; DC, discharge; EX, exercise ([†] $p < 0.01$ vs. age- and sex-matched group, ^{*} $p < 0.001$ vs. DC, [‡] $p < 0.05$ vs. post-EX training).

Table I

Subjects' physical and exercise characteristics (mean $\pm$ SD).

Characteristic	Discharge		Post-EX Training		Age-Sex Matched		3.5 y Postburn		Age-Sex Matched	
	Burned	40 (14/26)	Burned	40 (14/26)	Non-Burned [§]	p value	Burned	40 (14/26)	Non-Burned [§]	p value
n (male/female)		40 (14/26)		40 (14/26)	40 (14/26)			40 (14/26)		
Age (y)		13.2 $\pm$ 2.9		13.4 $\pm$ 3.0 [*]	13.4 $\pm$ 2.7	0.99	16.4 $\pm$ 2.9 [‡]	16.5 $\pm$ 3.2		0.99
Time of testing (months postburn)		1.9 $\pm$ 0.9		3.6 $\pm$ 1.4 [*]	—	—	42.0 $\pm$ 6.6 [‡]	—		—
TBSA burn (%)		49 $\pm$ 15		—	—	—	—	—		—
TBSA 3 rd -degree burn (%)		35 $\pm$ 21		—	—	—	—	—		—
Body Morphology										
Height (cm)		156 $\pm$ 14.2		156.3 $\pm$ 14.1	157.5 $\pm$ 14.6	0.99	163.4 $\pm$ 10.5 [‡]	168.1 $\pm$ 8.8		0.40
Weight (kg)		48.9 $\pm$ 12.1		52.7 $\pm$ 13.4	57.7 $\pm$ 21.6 [‡]	0.0001	64 $\pm$ 14.5 [‡]	64.2 $\pm$ 12.8		0.99
BSA (m ²)		1.4 $\pm$ 0.2		1.5 $\pm$ 0.3 [*]	1.6 $\pm$ 0.3	0.99	1.7 $\pm$ 0.2 [‡]	1.7 $\pm$ 0.2		0.99
BMI (kg·m ⁻²)		19.9 $\pm$ 3.4		21.2 $\pm$ 3.4	22.7 $\pm$ 6.1 [*]	< 0.02	23.9 $\pm$ 4.8	22.6 $\pm$ 3.5		0.71
BMI (%tile)		55.8 $\pm$ 33.2		67.2 $\pm$ 27.3 [*]	67.1 $\pm$ 26.8	0.26	69 $\pm$ 25.6 [*]	64.5 $\pm$ 21.9		0.99
Fat mass (kg)		12.9 $\pm$ 8.5		14.7 $\pm$ 6.6 [*]	14.1 $\pm$ 8	0.99	17.2 $\pm$ 9.1 [‡]	12.6 $\pm$ 4.4		0.01
Lean mass (kg)		34.4 $\pm$ 8.5		36.5 $\pm$ 9.3 [*]	41.6 $\pm$ 15.4 [*]	< 0.01	44.8 $\pm$ 9.1 [‡]	49.2 $\pm$ 10.8		0.30
BMC (kg)		1.6 $\pm$ 0.5		1.6 $\pm$ 0.5	1.9 $\pm$ 0.9	0.06	2.0 $\pm$ 0.4 [‡]	2.4 $\pm$ 0.7 [‡]		0.02
BMD (g·cm ⁻²)		1.0 $\pm$ 0.2		0.9 $\pm$ 0.1	1 $\pm$ 0.2	0.20	1.1 $\pm$ 0.1 [‡]	1.2 $\pm$ 0.2 [‡]		0.01
Peak aerobic capacity										
VO ₂ (L O ₂ ·min ⁻¹)		1.1 $\pm$ 0.4		1.6 $\pm$ 0.5 [*]	2.4 $\pm$ 1.0 [‡]	0.0001	2.3 $\pm$ 0.7 [‡]	3 $\pm$ 0.7 [‡]		< 0.0001
VO ₂ (mL O ₂ ·kg ⁻¹ ·min ⁻¹)		23.1 $\pm$ 5.3		29.7 $\pm$ 5.9	42.2 $\pm$ 8.1 [‡]	0.0001	42.2 $\pm$ 8.1 [‡]	46.4 $\pm$ 5.2		< 0.0001
VO ₂ (mL O ₂ ·kg ⁻¹ ·min ⁻¹)		32.6 $\pm$ 5.9		42.6 $\pm$ 6.6 [*]	57.5 $\pm$ 6.2 [‡]	0.0001	52.4 $\pm$ 11.3 [‡]	60.6 $\pm$ 4.9 [‡]		< 0.0001
RER		1.1 $\pm$ 0.2		1.2 $\pm$ 0.1	1.1 $\pm$ 0.1	0.99	1.1 $\pm$ 0.1	1.2 $\pm$ 0.1 [‡]		< 0.05
Peak heart rate (beats/min)		170 $\pm$ 20		178 $\pm$ 21	191 $\pm$ 14 [‡]	0.01	177 $\pm$ 18 [*]	190 $\pm$ 12 [‡]		0.007
Peak strength										
Peak torque (N·M)		50.7 $\pm$ 23.9		73.1 $\pm$ 28.2 [*]	99.3 $\pm$ 39.2 [‡]	0.001	100.4 $\pm$ 26.1 [‡]	134 $\pm$ 40.6 [‡]		< 0.0001
Peak torque (N·M·kg ⁻¹ ·LBM)		1.4 $\pm$ 0.5		1.9 $\pm$ 0.4 [*]	2.4 $\pm$ 0.3 [‡]	0.0001	2.2 $\pm$ 0.4 [‡]	2.7 $\pm$ 0.4 [‡]		< 0.0001

Characteristic	Discharge		Post-EX Training		Age-Sex Matched		3.5 y Postburn		Age-Sex Matched	
	Burned		Burned		Non-Burned [§]	<i>p</i> value	Burned		Non-Burned [§]	<i>p</i> value
Average power (W)	62 ± 31		94 ± 39 [*]		129 ± 60 ^{*,‡}	0.004	130 ± 60 ^{*,‡}		180 ± 56 [‡]	< 0.0001
Average power (W·kg ⁻¹ LBM)	1.7 ± 0.7		2.5 ± 0.7 [*]		3 ± 0.5 ^{*,‡}	0.0001	2.9 ± 0.6 ^{*,‡}		3.6 ± 0.6 [‡]	< 0.0001

BSA, body surface area; BMC, bone mineral content; BMD, bone mineral density; BMI, body mass index; BMI %ile, body mass index percentile for age; EX, exercise; LBM, lean body mass; RER, respiratory exchange ratio; TBM, total body mass; TBSA, total body surface area; VO₂, volume of oxygen.

[§]Data presented for two separate groups of age- and sex-matched controls selected for either the discharge and post-exercise comparisons (n=40) or the 3.5 year postburn comparison (n=40). Statistically different from

^{*} discharge time;

[‡] post-EX training time and

[‡] 3.5 y postburn.