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Effects of exercise training on resting energy expenditure and lean mass during pediatric burn rehabilitation

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Abstract

Objective—Severe burns cause profound hormonal and metabolic disturbances resulting in hypermetabolism, reflected in extreme elevation of resting energy expenditure (REE) and extensive skeletal muscle catabolism. Aerobic and resistive exercise programs during rehabilitation have shown substantial benefits, although whether such training potentially exacerbates basal metabolism is unknown. We therefore examined the effects of exercise training upon REE during the rehabilitation of severely burned pediatric patients.

Methods—Children with 40% total body surface area (TBSA) burns and greater were enrolled on admission to our burn intensive-care unit to participate in a twelve-week, hospital-based exercise program (EX), or a home-based standard of care program (SOC), commencing six months post-injury.

Results—Twenty-one patients (7–17 years) were enrolled and randomized to SOC (n=10) or EX (n=11). Age, gender, and TBSA burned were similar. Mean change (± sd) in REE, normalized to individual lean body mass (LBM), was almost negligible between SOC and EX group patients (0.03 ± 17.40%, SOC vs. 0.01 ± 26.38%, EX). A significant increase in LBM was found for EX patients (2.06 ± 3.17%, SOC vs. 8.75 ± 5.65%, EX; p=0.004), which persisted when normalized to height (0.70 ± 2.39%, SOC vs. 6.14 ± 6.46%, EX; p=0.02). Peak torque also improved significantly more in EX patients (12.29 ± 16.49%, SOC vs. 54.31 ± 44.25%, EX; p=0.02), reflecting improved strength.

Conclusion—Exercise training significantly enhanced lean mass and strength, without observed exacerbation of post-burn hypermetabolism. We therefore advocate use of exercise conditioning as a safe and effective component of pediatric burn rehabilitation.

Keywords

muscle strength; peak torque; hypermetabolism; indirect calorimetry; metabolic rate

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Introduction

Severe burn injuries exceeding 40% total body surface area (TBSA) lead to protein breakdown from skeletal muscle stores and the development of a prolonged and profound catabolic state associated with hypermetabolism (1), that is compounded by prolonged bed rest (2, 3) and can lead to major functional impairment and delay in rehabilitation.

Patients with severe burns exhibit elevation of basal metabolism to some of the highest rates observed following any type of trauma. Resting energy expenditure (REE) remains elevated despite healing of skin wounds and may remain so for up to 18 months following injury (4, 5). During acute admission, this rise in REE may be up to 180% of normal values, declining to 150% by the time of full wound healing at two months post-injury, and steadily decline to 115% of predicted at 12 months (5). Related clinical features during the rehabilitation phase include impairment of glucose metabolism throughout the first six months post-injury, as well as prolonged derangement of circulating hormones, including cortisol and insulin, together with elevated pro-inflammatory cytokines, found to persist for up to 36 months (4).

Supervised resistance and aerobic exercise programs, in addition to physical and occupational therapy, have been shown to offer considerable benefits during outpatient rehabilitation. These include improvements in passive and active range of joint movement,(6) muscle strength,(7–9) walking distance,(9), and lean body mass (7, 8), in addition to a significant reduction in the number of surgical interventions required for burn scar contractures (10). Despite these benefits however, concerns remained regarding exercise programs potentially exacerbating and further elevating REE following pediatric burn injury. In healthy subjects, REE is reported to increase acutely following aerobic and resistive exercise of adequate intensity and duration (11, 12). Presently unknown was whether this effect may further intensify hypermetabolism in burn patients, in whom metabolic rate is already unduly elevated. To address this issue, we examined the effects of an exercise training program during the rehabilitation of pediatric burn patients with pre-existing elevated REE in a prospective, randomized clinical trial. We hypothesized that when changes in REE were corrected for alterations in muscle mass, participants in an individualized exercise program would not display significant exacerbation of metabolism in comparison to standard of care patients.

Methods

This study was approved by the Institutional Review Board of the University of Texas Medical Branch, Galveston, Texas, and is registered as a clinical trial at ClinicalTrials.gov, identifier NCT00675714. Children (age range 7 – 17 years old) were enrolled in the study and underwent assessment during follow-up visits at six and nine months following injury. Patients with burn injuries of at least 40% total body surface area were randomized on admission to our pediatric burn intensive-care unit to either the intervention or standard of care group. Burn surface area was estimated by the rule-of-nines (13, 14), following the guidelines of the Advanced Burn Life Support Providers manual and subsequently confirmed by a burn surgeon in the operating room at wound excision. Informed consent was obtained from the parents or legal guardian of the child following admission, as well as child assent when applicable. Patients were excluded from the study if the diagnosis included one or more of the following: anoxic brain injury; severe behavioral, cognitive, or psychological disorders; quadriplegia; or traumatic limb amputations.

Enrolled patients were randomized to participate in either a 12-week hospital-based exercise program (EX), or continued participation in our standard of care program (SOC) of home-based physical and occupational therapy instructions. All patients received otherwise similar acute care and rehabilitation up until the six month follow-up attendance. Patients returned to the Shriners Hospitals for Children, Galveston (SHC-G), Texas for exercise testing at both 6- and 9-month time-points following injury (Figure 1). Once assessments were completed, patients in the SOC group participated in a conventional physical rehabilitation and occupational therapy program, intended to be performed for one hour twice daily. Following instructional and review appointments with the related therapists, this was continued as a home-based program over this period (10).

For EX group patients, the SOC program was supplemented with a supervised and individualized in-hospital exercise training routine during the 12-week period. Patients were regularly monitored and the program reviewed and adapted to meet specific patient requirements. In comparison, the patients in the SOC group during this period continued participation in a home-based physical rehabilitation and occupational therapy program without exercise training or regular supervision. The significant intervention for the EX group was therefore an exercise training program of confirmed frequency, intensity, duration, and participation.

Exercise Training Program

Patients randomized to the exercise group participated in a 12-week, hospital-based program between assessments, 6 and 9-months post-injury. Due to organizational and logistical reasons, including significant distances due to travel, this program is routinely administered whilst patients remain as resident out-patients with their families or caregivers in apartments either within our hospital or local vicinity. The exercise program follows that previously described by our group, and shown to improve muscle strength, total work and average power in pediatric burn patients (7).

Exercise training programs were designed to include both resistance and aerobic exercises. No patients had previously participated in an exercise training program prior to enrollment. Each patient in the EX group received a program devised following evaluation by an exercise physiologist, and administered and supervised by an exercise specialist or technician.

During the first week of training, EX patients were familiarized with the exercise equipment and instructed in proper weight-lifting techniques. Eight basic resistance exercises were used, incorporating bench press, leg press, shoulder press, leg extension, biceps curl, leg curl, triceps curl, and toe raises. Initially, each patient lifted a weight or load set at 50–60% of their individual three repetition maximum (3RM). Lifting load was gradually increased during the second week to 70–75% (4–10 repetitions) of individual 3RM and was continued during week 2 up to the end of week 6. At this stage, training intensity was increased to 80–85% (8–12 repetitions) of the 3RM and continued during weeks 7–12.

Additionally, each exercise training session also included aerobic conditioning exercises on a treadmill or cycle ergometer. This aerobic training was carried out three days per week, with each session lasting 30 minutes, with participants exercising at 70–85% of their previously determined individual peak aerobic capacity (VO2 peak). All exercise sessions were preceded by a 5-min warm-up period on a treadmill set to an intensity of 50% of each individuals VO2 peak.

Rating of perceived exertion was obtained at regular intervals during aerobic exercise training according to the scale described by Borg (15). Heart rate and oxygen saturation were monitored using a pulse oximeter (Ohmeda Medical, Plymouth, MN). Exercise prescriptions and sessions were supervised at all times by an exercise specialist, and conducted according to the guidelines set by the American College of Sports Medicine and the American Academy of Pediatrics (16–18). Additional strength-training activity was not permitted outside the supervised training session. At no time did EX group patients train using the Biodex dynamometer (Biodex Medical Systems, Shirley, NY) that was used to conduct assessments. All patients were advised and encouraged to pursue normal daily activities.

Standard of Care Program

The standard of care rehabilitation program comprises a series of interventions typically offered at most US burn centers, and at our unit consists of evaluation appointments with physical and occupational therapists, supplemented with instructions for a home-based physical rehabilitation routine.

Patients in the SOC program participated in a 12-week, home-based physical rehabilitation program, although without specific individualization or supervision of the exercise routines performed. The program aims to maintain and enhance range of movement, and minimize scar deformities and contractures. It includes range of motion and strength exercises (not progressive resistance training), positioning and splinting routines, in addition to scar management techniques including pressure garments, inserts, and physical agent modalities (10). Therapists assess and confirm that a patient's parent or guardian is able to comply with detailed step-by-step instructions provided for the home program.

This program is implemented for all patients (both SOC and EX group patients) starting at discharge up to 6-months. Subsequently, patients in the SOC group then continued in this program at home during the 12-week study period. The SOC group did not receive an exercise prescription by an exercise physiologist at any time during the study and adherence to exercises were not monitored. This was in contrast to the EX group, where greater than 90% compliance to an exercise prescription was maintained.

Assessments

Exercise testing was conducted for both SOC and EX groups in the Wellness & Exercise department of SHC-G. Patients sat quietly for 15 minutes before resting parameters were recorded. Assessments were conducted following familiarization with the testing equipment and instructions given regarding proper weight-lifting techniques.

Strength Assessment—Strength assessment was performed according to manufacturer instructions using the Biodex System 3 dynamometer (Biodex Medical Systems, Shirley, NY). Isokinetic (concentric) testing of knee extensor strength of the patient's dominant leg was performed at an angular velocity of 150°/s. This speed was chosen so as to be well tolerated by children of all ages in both groups.

All patients were made familiar with the testing equipment in the same manner. Patients were seated and their position stabilized with a restraining strap placed over the mid-thigh, pelvis, and trunk, in accordance with the Biodex System 3 manual. The test administrator initially demonstrated and explained the procedure, after which the patient practiced the actual movement without load as warm-up, performing three sub-maximal repetitions. More repetitions were not permitted to prevent the onset of fatigue. The anatomic axis of the knee joint was aligned with the mechanical axis of the dynamometer before the test. After the sub-maximal warm-up repetitions, 10 maximal voluntary muscle contractions (full extension and flexion) were performed consecutively, without resting between contractions. The test was repeated following three minutes of rest to minimize the effects of fatigue. Peak torque values were calculated with the Biodex software system. The highest peak torque measurement attained from the two trials was selected. Peak torque was corrected for gravitational moments of the lower leg and the lever arm.

Lean Body Mass Assessment—Lean body mass (LBM) measurements were obtained for both groups by dual energy X-ray absorptiometry (DXA) using the QDR 4500A densitometry system (Hologic Inc., Bedford, MA) according to manufacturer instructions(19) as previously described by our group (5). Scans were taken with the patient lying supine on the scanning table. This is a non-invasive procedure with a low radiation dose. We followed the previously described protocol for obtaining a whole body scan. The technique is used to determine bone mineral density as well as total body composition. Using pediatric software, DXA measures the attenuation of two X-ray beams of differing energy levels, and these measurements are then compared with standard models of thickness used for bone and soft tissue. Measurements for soft tissue are subsequently separated and reported in grams of LBM and fat mass.

Peak oxygen consumption assessment—All subjects underwent a standardized treadmill exercise test on day 2, using the modified Bruce protocol as part of their standard clinical outpatient evaluation. Heart rate and oxygen consumption (VO2) were measured and analyzed using methods previously described (7, 20). Briefly, breath-by-breath analysis was continuously made of inspired and expired gases, flow, and volume by using a Medgraphics CardiO2 combined O2/ECG exercise system (St. Paul, MN). Speed and angle of elevation started at 1.7 miles/h and 0%, respectively. The speed and level of incline were subsequently increased every three minutes. Subjects were constantly encouraged to complete three-minute stages, and the test was terminated once peak volitional effort was achieved. The VO2 peak and peak heart rate were used to aid in establishing the intensity at which patients in the EX group exercised during the 12 weeks of training.

Resting energy expenditure assessment—Patients were fasted from 10pm to 6am prior to early morning measurements of REE between 6 and 8am. Resting energy expenditure was measured using a Sensor-Medics Vmax 29 metabolic cart (Yorba Linda, CA). Subjects were tested in a supine position while under a large, clear, ventilated hood. Expired gas samples were analyzed breath by breath, and only measurements from steady states were considered for the analysis. Steady states were defined as intervals of time, from a minimum of 5 minutes, during which every average minute oxygen consumption and carbon dioxide production changed by less than 10% (21). The REE was calculated from the oxygen consumption and carbon dioxide production by equations described by Weir (22). All indirect calorimetry measurements were made at 22°C and after 8–12 hours of fasting. Inspired and expired gases were continuously measured. Values of carbon dioxide production, VO2, and REE were accepted when they were at a steady state for 5 min. The average REE was calculated from these steady-state measurements of 20 min. Measurement of REE was performed at least 96 hours after the exercise evaluation. Resting energy expenditure was determined by indirect calorimetry performed by trained respiratory therapists. Estimated basal energy expenditure, based on age, sex, height and weight, was calculated using the Harris-Benedict equation (23) in order to normalize measured REE values to a percentage of predicted expenditure. Based on this equation, 90% is given as a normal value for percentage predicted REE in unburned individuals (24).

Statistical analysis was performed by Student's paired t-test and Fisher's exact test, as appropriate, with significance set at p-value <0.05, using the Sigmastat software package (v3.5, Systat Software Inc, San Jose, CA). All values are presented as mean ± standard deviation in the text and tables; and ± standard error of the mean in figures.

Results

Demographics

Twenty-one patients were enrolled in the study (16 boys and 5 girls) ranging from 7–17 years old (13.7 ± 3.6, SOC vs. 12.2 ± 3.2 years, EX), with 10 patients randomized to the SOC and 11 patients to the EX group. Age at admission, gender distribution, burn to admission time, total body surface area (TBSA) burned and percentage 3rd degree burned, length of ICU stay, and burn mechanism were similar in both groups, with no significant differences found across these demographic characteristics (Table 1).

Height & Weight

Mean gain in height was minimal over the 12 week study period and similar for both groups (0.67 ± 1.34%, SOC vs. 1.25 ± 1.56%, EX) representing a mean gain of less than 2cm for either group, within measurement error. Mean gain in weight was considerably greater for the EX group (3.60 ± 3.76%, SOC vs.11.07 ± 13.09%, EX), the difference found to be statistically significant within the EX group over the study period (p=0.01, Table 2), although did not reach statistical significance between the groups (p = 0.10).

Resting Energy Expenditure

The mean change in REE for the EX group compared to SOC was greater (2.32 ± 19.79%, SOC vs. 8.79 ± 29.45%, EX) but was not statistically significant (p =0.57). This difference decreased when normalized as a percentage of predicted REE (2.20 ± 22.06%, SOC vs. 3.64 ± 37.81%, EX) and was similarly non-significant (p=0.92, Figure 2). Additionally, no statistically significant difference in REE or percent predicted REE was found over the study period within either group (Table 2), although a slight increase in both parameters was found in each group.

When REE was normalized to measurements of individual LBM at each time-point (REE/LBM), no significant change occurred within either group, though did decrease in the EX group (Table 2). Expressed as mean percent change, the difference between the groups became almost negligible (0.03 ± 17.40%, SOC vs. 0.01 ± 26.38%, EX), indicating that any elevation in individual REE for EX patients was matched by a corresponding increase in LBM.

Lean Body Mass

Patients in the EX program gained significantly greater lean body mass (2.06 ± 3.17%, SOC vs. 8.75 ± 5.65%, EX; p=0.004). This difference persisted when measurements were normalized to height (LBM index = LBM divided by height squared), (0.70 ± 2.39%, SOC vs. 6.14 ± 6.46%, EX; p=0.02, Figure 3), indicating differences in LBM were less likely due to confounding factors, such as pre-existing physical differences between the groups or variation in growth rates. A significant rise in LBM and LBM index over the study period was seen only in the EX group (Table 2).

Strength

Two patients from the EX group were unable to undergo strength assessment, one due to recent surgery and one due to leg mobility issues and wheel-chair use. Two patients in the SOC were also unable or declined to undergo strength assessment. Improvement in peak torque was significantly greater in the EX group (12.29 ± 16.49%, SOC vs. 54.31 ± 44.25%, EX; p=0.02), reflecting enhancement of muscle strength. Peak torque measurements were also normalized to individual changes in LBM index (PKT/LBM Index, Table 2), with a statistically significant difference in percent increase found to persist between EX and SOC groups (11.4 ± 15.4%, SOC vs. 45.3 ± 38.3 %, EX; p=0.03, Figure 4). A rise in peak torque was seen in both groups over the study period, although was significant only in the EX group, and persisted when normalized to LBM Index (p=0.007, Table 2).

Discussion

We have previously reported on the benefits of a 12-week structured exercise training program during the rehabilitation of burned children, which include improvements in lean body mass (LBM), muscle strength, and power (7, 8), with LBM continuing to improve three months following cessation of supervised exercise training (8). The present study therefore confirms previous findings of improvement of LBM and strength, with the novel feature investigated in this study being the effects of exercise training on resting energy expenditure (REE) in children following severe burns. A small increase in REE over the study period was reported in both EX and SOC groups, although this increase was minimal over the study period, and no significant difference was found between groups, or between time-points within each group. Furthermore, when REE measurements were normalized to corresponding changes in LBM, these differences became negligible, indicating that any exercise-induced elevation of REE in EX patients was matched by a corresponding change in lean mass.

All but one patient in the EX program gained significantly more LBM over the study period compared to the mean gain for SOC patients, which together with significant improvements in peak torque (PKT), reflected enhanced functional strength in EX patients. These benefits occurred despite any potential negative effect of exercise to exacerbate hypermetabolism, which was not observed in this study. Gain in body weight over the study period within the EX group also suggested that the balanced aerobic and resistive exercise program was successful in developing LBM, and did not lead to any exercise induced weight-loss.

One patient in the EX group recorded a 17% drop in body weight, together with a 5% decline in LBM over the study period and was therefore reviewed in further detail. This was the only EX group patient where a fall in LBM was observed. This patient suffered a large TBSA flame burn (89%), which may therefore have limited rehabilitation activity up until the 6-month time-point. The weight loss appeared to be accounted for primarily by loss of body fat, which decreased from 27% to 17% over the study period. However, PKT also improved by 50% despite the decrease in LBM, and because of the patient’s young age, we speculate this may suggest neural-adaptation as a cause for the observed improvement (25, 26).

Our results indicate that exercise did not further exacerbate the hypermetabolic state, a characteristic feature of children following severe burn injury. Detrimental effects leading to a rise in REE is a cause of particular concern following severe burn injuries, as these patients are known to exhibit extreme and prolonged elevation in REE following injury (5, 24). Various studies in non-burned subjects have reported that exercise training increases REE, varying from an increase of 6% in REE in response to an 11-week aerobic training program (27) to a 12% rise in REE to 10 weeks of aerobic exercise (28), though both of these studies were in adults and consisted of aerobic training only. Other studies that have looked at the effects of resistance training on REE have also reported an increase in REE (29, 30). However, all of these studies were in adults and furthermore, all have evaluated either aerobic training or resistance training individually. Our results may therefore not be directly comparable to these studies.

A few studies have also focused on the effects of exercise training on REE in obese children, again with mixed findings reported. A significant increase in REE was reported for obese boys aged 9–12 following a three-month supervised aerobic and resistance training program (31). Conversely, five months of strength training in pre-pubertal obese girls did not significantly increase resting energy expenditure (32).

Other studies in non-burned subjects have demonstrated similar findings to those reported by our study, showing REE to be unaffected by exercise training or even reduced (33–36). These include a prospective-randomized study by Broeder et al. in which REE was reported not to significantly change in young male adults in response to a high intensity resistance exercise program or an aerobic endurance program (33). Nutritional intake was also monitored but not controlled for in this study, with no difference found in energy intake between exercising groups or controls, although controls were found to consume significantly greater calories as fat. A further cross-sectional study by the same group found REE not to be significantly different between trained and untrained male individuals when normalized to fat-free weight (34). Indeed, a potential criticism of our study was that nutritional intake was not controlled or monitored, although this was not part of the study design and would be difficult to implement in a pediatric population of various ages. In our study, body weight increased in both groups, although only EX patients increased significantly, with no significant difference in weight gain found between groups. If EX patients potentially had a greater nutritional intake or enhanced appetite, we speculate that this would still not be expected to cause direct increases in LBM or strength without an intervention.

In a review by Westerterp, no clear long-term effect of exercise training on REE was established from five different studies examined, although fat-free mass tended to increase considerably, and measured energy expenditure appeared to be twice as high as calculated expenditure (36). It has also been postulated that the effect of an exercise intervention on energy expenditure decreases with time as efficiency at the exercise improves (36, 37). Finally, a study reported a decrease in REE (normalized to LBM) in adolescent girls participating in rowing training, compared to their non-training peers over a four year study period (35).

A potential drawback of our study includes the possibility of a type II error, which cannot be ruled out completely with regards to the effects of exercise on REE. We recognize that the number of subjects in both groups may not allow rejection of the null hypothesis, although rejection may be justified. Our findings indicate that the exercise training program, implemented at six months following severe burn injury, did not further increase REE, and that furthermore, exercise training resulted in a beneficial increase in LBM, despite pre-existing elevation of REE.

In conclusion, our results support the findings of other investigators that exercise training does not further exacerbate REE. In children with major burns, a population which is hypermetabolic for up to one year after injury, exercise training used as a rehabilitation tool did not further exacerbate the hypermetabolic state. We therefore advocate the use of exercise conditioning as a safe and effective component of pediatric burn rehabilitation.

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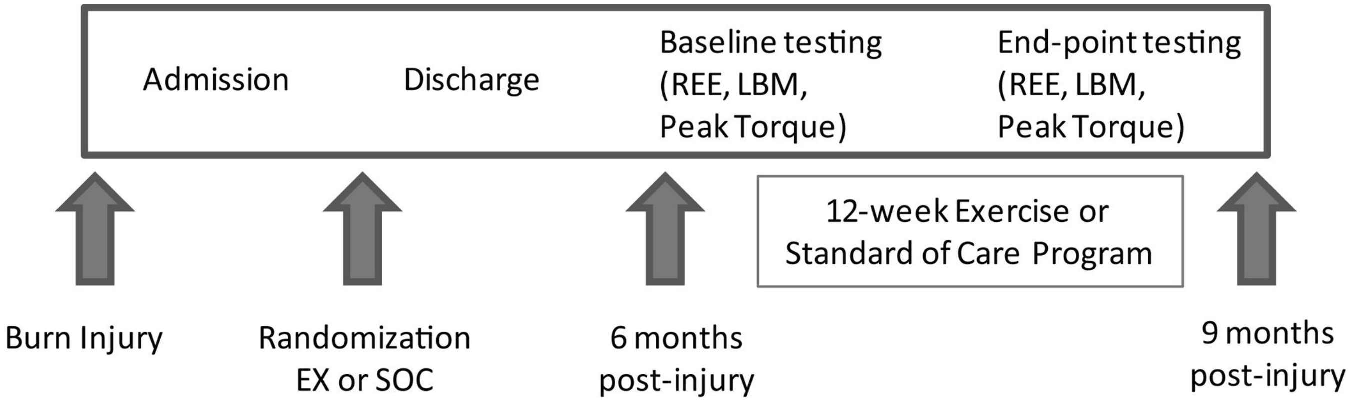

Figure 1.

Study design flowchart with time-points and testing performed. Following randomization and acute care, patients participated in either a 12-week standard of care program or aerobic and resistance exercise program commencing at 6-months post-injury following baseline testing, with end-point testing completed at 9-months.

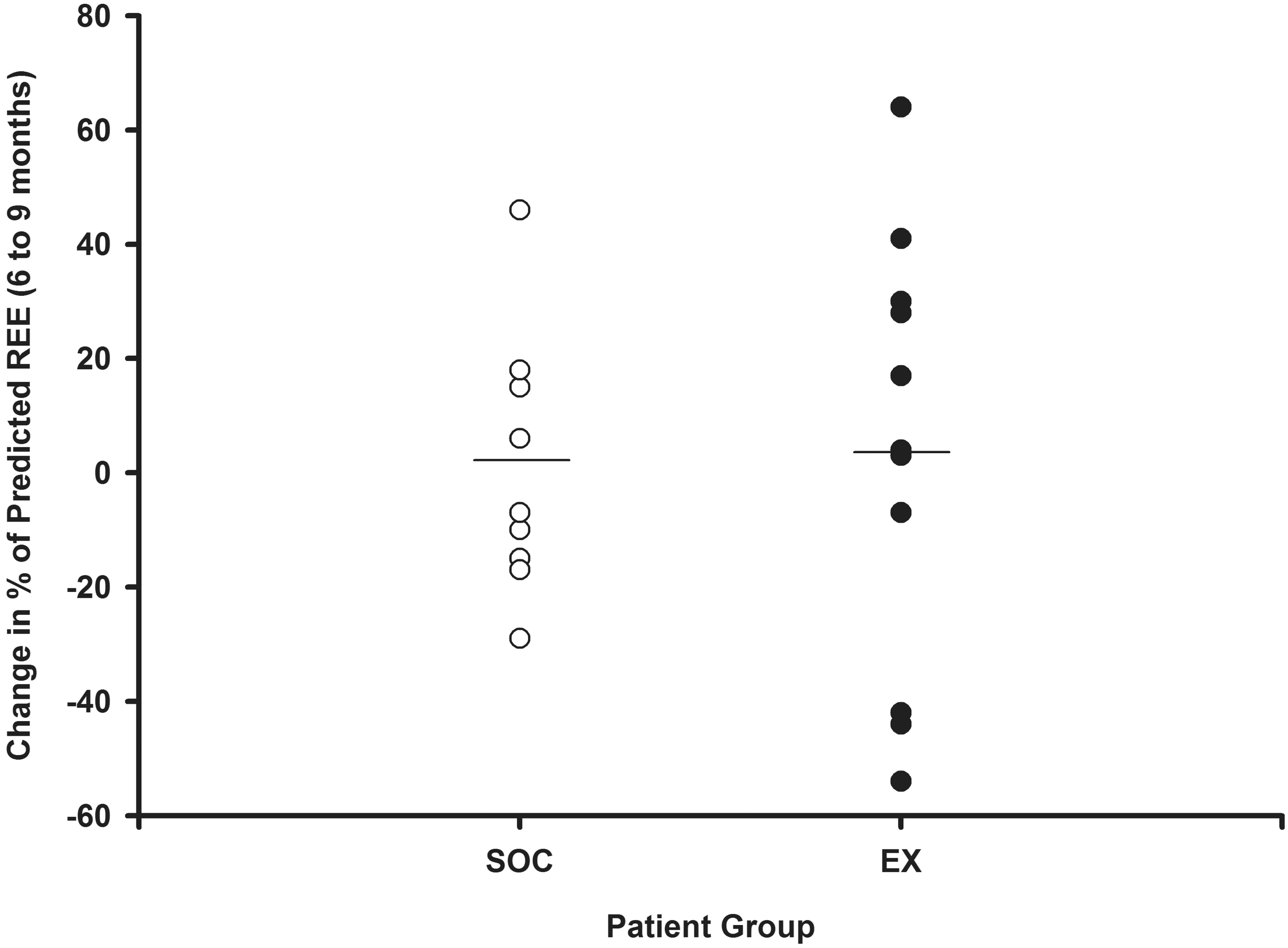

Figure 2.

Change in Resting Energy Expenditure (REE) expressed as percentage of predicted value during the 6 to 9 month post-burn study period. Standard of care (SOC) and exercise (EX) patient group results shown as individual percentage change. Horizontal line represents group mean. A statistically significant difference between patient groups was not demonstrated.

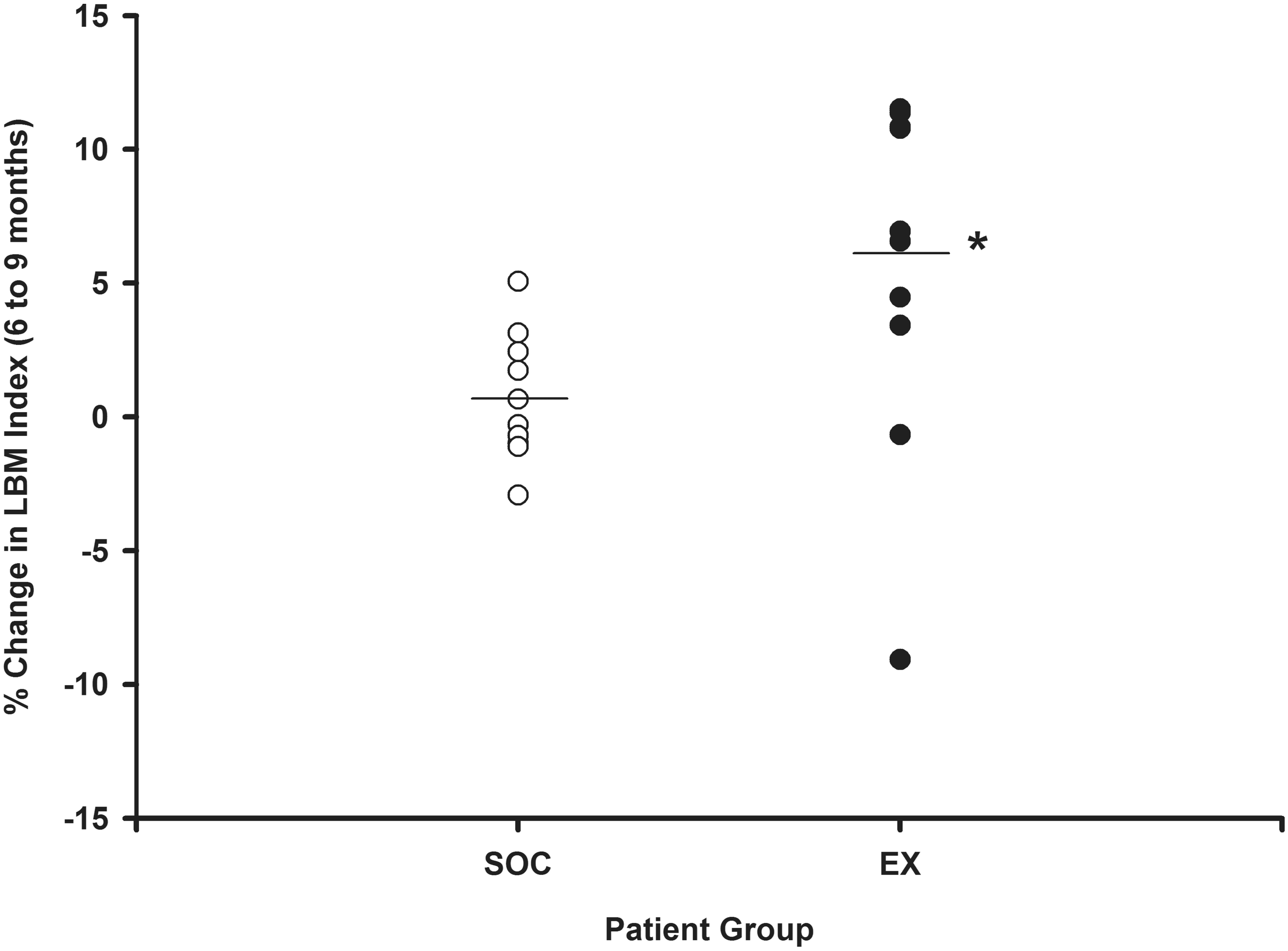

Figure 3.

Change in Lean Body Mass (LBM) Index (LBM normalized to inverse of height-squared) during the 6 to 9 month post-burn study period. Standard of care (SOC) and exercise (EX) patient group results shown as individual percentage change. Horizontal line represents group mean. * Indicates statistically significant difference to SOC patient group observed ($p < 0.05$).

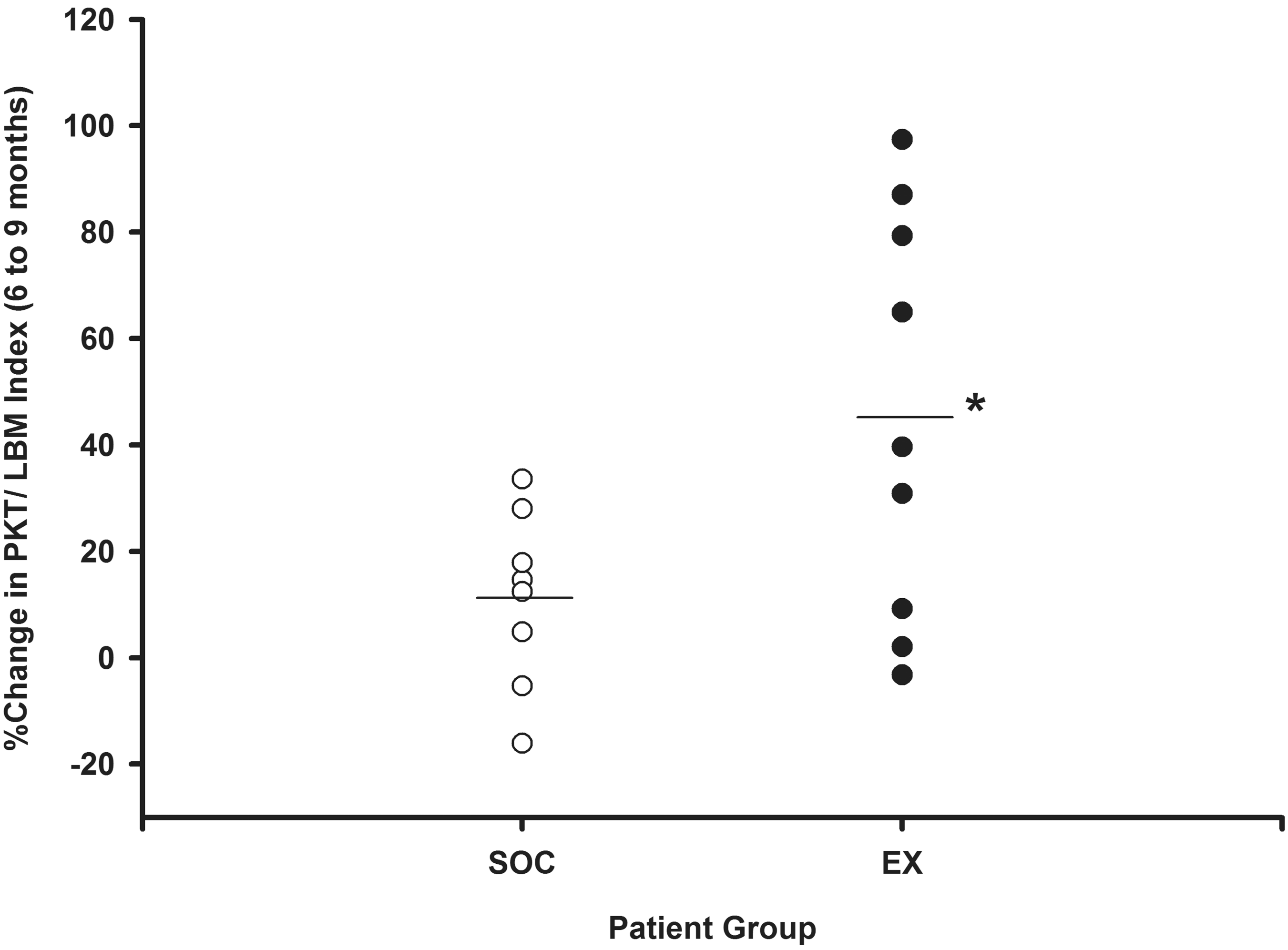

Figure 4.

Change in Peak Torque normalized to Lean Body Mass Index (PKT/LBM Index) during the 6 to 9 month post-burn study period. Standard of care (SOC) and exercise (EX) patient group results shown as individual percentage change. Horizontal line represents group mean. * Indicates statistically significant difference to SOC patient group observed ($p < 0.05$).

Table 1

Demographic characteristics of standard of care and exercise patient groups.

Group Demographic	Standard of Care (n = 10)	Exercise (n =11)	p-value
Age on admission (years)	13.7 ± 3.6	12.2 ± 3.2	ns
Gender (male: female)	7:3	9:2	ns
Burn to admit time (days)	6 ± 5	6 ± 7	ns
TBSA (%)	56 ± 15	61 ± 13	ns
TBSA 3rd degree (%)	52 ± 16	45 ± 25	ns
ICU length of stay (days)	28 ± 11	49 ± 37	ns
Burn type			
Flame (%)	90	91	ns
Electrical/ Flame (%)	10	9	ns

Values shown as mean ± standard deviation; n, number of patients; TBSA, total body surface area burned, TBSA 3rd degree, TBSA full-thickness burn. ns, p-value non-significant

Table 2

Measured parameters for standard of care and exercise patient groups at 6 and 9 month time-points (with p-value reported for paired student's t-test for difference within patient group).

Group Parameter	**Standard of Care (n = 10)**			**Exercise (n =11)**		
	6 months	**9 months**	**p-value**	**6 months**	**9 months**	**p-value**
Height (cm)	153 ± 17	154 ± 18	0.16	150 ± 23	152 ± 24	**0.03**
Weight (kg)	46.4 ± 22.3	48.3 ± 24.3	0.09	45.4 ± 22.5	50.1 ± 23.8	**0.01**
REE (kcal/day)	1480 ± 354	1510 ± 477	0.78	1533 ± 354	1651 ± 551	0.41
% Pred REE (%)	107 ± 15	109 ± 24	0.76	116 ± 22	119 ± 25	0.76
REE/LBM (kcal/kg/day)	45.6 ± 11.9	45.3 ± 13.2	0.93	54.1 ± 23.6	50.4 ± 16.1	0.51
LBM (kg)	35.7 ± 16.0	36.6 ± 17.0	0.14	33.0 ± 14.9	36.0 ± 16.4	**0.001**
LBM index (kg/m^2)	14.6 ± 4.0	14.7 ± 4.2	0.44	13.9 ± 3.4	14.7 ± 3.4	**0.01**
Peak Torque (N.m)	57.8 ± 37.7	63.9 ± 43.1	0.12	41.2 ± 38.7	52.3 ± 39.9	**0.004**
PKT/LBM Index ($N.m/kg/m^2$)	3.7 ± 1.7	4.0 ± 1.8	0.08	2.6 ± 2.0	3.2 ± 2.0	**0.007**

Values shown as mean ± standard deviation; n, number of patients; REE, resting energy expenditure, % Pred REE, REE expressed as percentage of predicted; LBM, lean body mass, LBM Index, LBM × height $^{-2}$; PKT, peak torque. Reference values in non-burned, age-matched children: LBM = 46.8 ± 21.7 kg; Peak Torque = 80.0 ± 34.9 N.m (Suman et al 2007) (27)