Effects of a 12-wk resistance exercise program on skeletal muscle strength in children with burn injuries

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SEVERE BURN INJURY RESULTS in persistent and extensive skeletal muscle catabolism and weakness (17), which is confounded by prolonged physical inactivity (12). Current standard treatment includes a rehabilitation program consisting of occupational and physical therapy typically implemented for a 12-wk period, which can be administered in the hospital setting or at the patient’s home. However, muscle catabolism and weakness persist despite therapy. The physical frailty associated with severe burn injury is often confounded by the presence of cardiac and systemic shock, hypermetabolism, respiratory injury, sepsis, postburn seizures, compromised bone formation, major surgeries, malnourishment, disturbed growth patterns, and psychosocial issues (4, 17, 20, 24, 39). Additionally, low physical work capacity and muscle strength are major obstacles in allowing the burn victim to return to school and to perform activities of daily living.

Two well-known results of resistive exercise in adults are an increase in muscle strength and hypertrophy (25). Because activities of daily living are integrated functions requiring muscle strength and endurance, an effective resistance exercise program may contribute to the rehabilitation of severely burned children by increasing muscular strength and the capacity to do work (15, 32, 37). Previous studies in nonburned children have demonstrated an increase in muscle strength as a result of resistance exercise (9, 11, 34, 35), although its effects on muscle mass remain controversial (11, 35). Despite the extensive amount of literature on the effects of resistance exercise in healthy, nonburned children, there is a lack of data on the effects of resistance exercise on muscle strength, mass, and work and on its benefits on the physical rehabilitation of individuals with burn injury. Therefore, we designed a study to assess whether children with thermal injury would benefit from an exercise training program by increasing muscle mass, strength, and capacity to do work.

METHODS

Subjects. Thirty-five children, ages 7–17 yr old, were enrolled in this study. Only patients with >40% of total body surface area (TBSA) burned, as assessed by the “rule of nines” method (19) during excisional surgery in the acute phase of injury, were enrolled. Patients were excluded if they had one or more of the following: leg amputation, anoxic brain injury, psychological disorders, quadriplegia, or severe behavior or cognitive disorders. Informed consent was given by the parent or legal guardian during the first day of acute admission. After informed consent was obtained, patients were randomized into two groups. One group was to participate in a 12-wk in-hospital physical rehabilitation program supplemented with an individualized and supervised exercise training program (REx; n = 19). The nonexercising group (R; n = 16) was to participate in a 12-wk, home-based physical rehabilitation program without individualization and supervision of exercise.

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All patients received similar standard medical care and treatment from the time of emergency admission and acute care of the burn injury until time of discharge. In addition, both groups were discharged with similar standard medical and rehabilitation care until the 6 mo post-burn injury time point. Both groups included children that received a subcutaneous daily injection of 0.05 mg/kg of recombinant human growth hormone for 9 mo as part of a separate study investigating the effects of growth hormone in burn injuries. However, an equal number of subjects receiving growth hormone were distributed between the groups (3 in each group).

At 6 mo post-burn injury, all patients returned to Shriners Hospitals for Children for exercise testing. After completing the exercise tests, the REx group began participating in the 12-wk in-hospital physical rehabilitation program supplemented with an individualized and supervised exercise training program. In contrast, the R group began participating in the 12-wk, standard home-based physical rehabilitation program without exercise. However, both groups participated in a physical rehabilitation program which consisted of 12-wk of conventional occupational therapy and physical therapy twice daily for 1 h. Patients in the R group did not receive an exercise prescription by an exercise physiologist at any time during the study. The major differences between REx and R groups were the training frequency, intensity, duration, and participation in an exercise program. This study was approved by the Institutional Review Board.

Exercise testing. Exercise assessments were conducted at the beginning of 6 mo and at the end of 9 mo post-burn injury. Before strength testing, the patient was familiarized with the exercise equipment and instructed on proper weight-lifting techniques. The patient was asked to sit quietly for ~15 min before resting measurements were recorded. After this time period, vertical height and body weight was measured.

Strength measurements. Strength testing was conducted on day 1 of the 6- and 9-mo post-burn injury period using a Cybex Norm dynamometer (Ronkonkoma, NY). The isokinetic test was performed on the dominant leg extensors and tested at an angular velocity of 150°/s. The patients were seated and their position stabilized with a restraining strap over the midthigh, pelvis, and trunk in accordance to the Norm Testing and Rehabilitation System User’s Guide. All patients were familiarized with the Cybex test in a similar manner. First, the procedure was demonstrated by the administrator of the test. Second, the test procedure was explained to patients, and, third, patients were allowed to practice the actual movement during three submaximal repetitions without load as warm-up. More repetitions were not allowed 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 three submaximal warm-up repetitions, 10 maximal voluntary muscle contractions (full extension and flexion) were performed. The maximal repetitions were performed consecutively without rest in between. Three minutes of rest were given to minimize the effects of fatigue and the test was repeated.

Values of peak torque, total work, and average power were calculated by the Cybex software system. The highest peak torque, total work and average power measurements between the two trials were selected. Peak torque was corrected for gravitational moments of the lower leg and the lever arm.

Isometric strength testing was completed on the Cybex after a 3-min rest after the isokinetic test. The isometric test assessed the peak torque during a peak isometric voluntary contraction of the dominant knee extensors. The knee joint was positioned at 90°, and, at a signal, the subject tried to extend the lower leg with a maximal effort against the immovable attachment arm for 5 s. Three separate attempts were performed with 3-min rest intervals between each peak voluntary contraction, and the highest value of the three trials was recorded as peak isometric torque.

Three-repetitions maximum test. After a 30-min rest period, patients enrolled in the REx group were tested to determine the amount of weight or load that would be used during the first week (of the 12-wk program) as baseline loads. They were tested in the following order of exercises: bench press, leg press, shoulder press, leg extension, biceps curl, leg curl, and triceps curl. The three-repetitions maximum (3-RM) load was determined as follows. After an instruction period on correct weight-lifting technique, the patient warmed up with lever arm and bar (or wooden dowel) and allowed to become familiar with the movement. After this, the patient lifted a weight that allowed successful completion of four repetitions. If the fourth repetition was achieved successfully and with correct technique, a 1-min resting period was allowed. After the resting period, a progressively increased amount of weight or load was instructed to be lifted at least four times. If the patient lifted a weight that allowed successful completion of three repetitions, with the fourth repetition not being volitionally possible, because of fatigue or inability to maintain correct technique, the test was terminated and the amount of weight lifted from the successful set was recorded as their individual 3 RM.

Lean body mass measurements. On day 2 (6 and/or 9 mo), lean body mass (LBM) measurements were made for both groups by dual-energy X-ray absorptiometry (DXA) using the QDR 4500A software (Hologic, Waltham, MA). Scans were taken with the patient lying supine on the scanning table. The protocol for obtaining a whole body scan was done according to the manufacturer’s instructions (21) and has been described by our group (18). Briefly, DXA with pediatric software can measure the attenuation of two X-ray beams, one which is high energy and one which is low energy. These measurements are then compared with standard models of thickness used for bone and soft tissue. Subsequently, the calculated soft tissue is separated into LBM and fat mass. LBM is reported in grams.

Peak oxygen consumption. 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 (V̇O₂) were measured and analyzed by using methods previously described (23). Briefly, breath-by-breath analysis was continuously made of inspired and expired gases, flow, and volume by using a Medgraphics Cardió2 combined V̇O₂/ECG exercise system (St. Paul, MN). Speed and angle of elevation started at 1.7 miles/h and 0%, respectively. Thereafter, the speed and level of incline were increased every 3 min. Subjects were constantly encouraged to complete 3-min stages, and the test was terminated once peak volitional effort was achieved. The peak V̇O₂ (V̇O₂ peak) and peak heart rate were used to establish the intensity at which patients in the REx group exercised during the 12 wk of training.

Resting energy expenditure. Resting energy expenditure (REE) was measured on day 4, between 12 midnight and 5:00 AM, by using a Sensor-Medics 2900 metabolic cart (Yorba Linda, CA). All indirect calorimetry measurements were made at 22°C and after 8–12 h of fasting. Inspired and expired gases were continuously measured. Values of carbon dioxide production, V̇O₂, 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. Posttraining REE was measured an average of 96 h after the last exercise session.

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Exercise training program. All subjects were sedentary before starting the exercise program and had never participated in an exercise training program. Each exercise training session consisted of resistance and aerobic exercises. Eight basic exercises were used: bench press, leg press, shoulder press, leg extension, biceps curl, leg curl, triceps curl, and toe raises. At no time did the REx group train using the Cybex dynamometer. All exercises were done using variable-resistance machines or free weights. During the first week of training, the patients became familiarized with the exercise equipment and were instructed in proper weight-lifting techniques. The weight or load the subjects lifted was set at 50–60% of their individual 3 RM. During the second week, the lifting load was increased to 70–75% (4–10 repetitions) of their individual 3 RM and continued for weeks 2–6. After this, training intensity was increased to 80–85% (8–12 repetitions) of the 3 RM and implemented from weeks 7–12.

Each exercise training session also included aerobic conditioning exercises on a treadmill or cycle ergometer. This aerobic training was carried out 3 days/wk. Each session lasted 20–40 min, and participants exercised at 70–85% of their previously determined individual VO$_2$ peak. All exercise sessions were preceded by a 5-min warm-up period on the treadmill at an intensity of <50% of each individual VO$_2$ peak. Heart rate and oxygen saturation were monitored by using a pulse oximeter (Ohmeda Medical, Plymouth, MN). Rate of perceived exertion was obtained at regular intervals during aerobic exercise. All exercise sessions and exercise prescriptions were supervised by an exercise specialist and were conducted according to the guidelines set by the American College of Sports Medicine and the American Academy of Pediatrics (1–3). No strength-training activities were permitted outside the supervised training session; however, both groups were allowed to pursue their normal daily activities.

Data analysis. All data in the text and tables are expressed as means ± SE. The effects of exercise on the dependent variables were analyzed by paired t-tests for within-group comparisons over time (12 wk) and by unpaired t-tests for between-group comparisons before and after 12 wk of intervention. A $P$ value < 0.05 was considered statistically significant. Corrections for differences in total LBM were made by dividing peak torque, total work, and average power by total LBM.

RESULTS

Thirty-five children were enrolled in the study (28 boys, 7 girls). Nineteen REx patients and sixteen R patients were tested at 6 and 9 mo postburn. The range in age for the REx and R groups was 7–17 yr. There were no differences at 6 mo postburn between the groups in age, percent TBSA burned, vertical height, standing weight, and body surface area. At 9 mo postburn, both groups had similar levels of age, vertical height, and standing weight. Additionally, standing weight, vertical height, and TBSA burned remained relatively unchanged at 9 mo postburn in either group compared with 6 mo postburn (Table 1).

Corrections for differences in total LBM were made by dividing peak torque, total work, and average power by total LBM. However, similar statistical results were obtained with and without normalization. Therefore, uncorrected absolute strength values are presented throughout the manuscript. There was a significant increase in strength (reflected by peak torque), total work, and average power after 12 wk of exercise intervention in the REx, but not in the R, group. Peak torque increased 44.4% in the REx group vs. 5.60% in the R group. Similarly, total work and average power increased 78.5 and 72.3%, respectively, in the REx group vs. 2.10 and 8.30%, respectively, in the R group. Comparison of the mean percent change in peak torque, total work, and average power obtained revealed a significant difference between groups (Fig. 1). Mean values obtained for peak torque, total work and average power are reported on Table 2.

Table 1. Demographic characteristics of patients at 6 and 9 mo postinjury

<table>
<thead>
<tr>
<th>Gender distribution</th>
<th>REx (n = 19)</th>
<th>R (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mo</td>
<td>9 mo</td>
<td>6 mo</td>
</tr>
<tr>
<td>Age, yr</td>
<td>10.5 ± 0.92</td>
<td>10.8 ± 0.92</td>
</tr>
<tr>
<td>Burn size (TBSA), %</td>
<td>59.4 ± 3.30</td>
<td>59.4 ± 3.30</td>
</tr>
<tr>
<td>Height, cm</td>
<td>143.3 ± 5.50</td>
<td>144.6 ± 5.30</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>40.6 ± 4.75</td>
<td>43.1 ± 5.04</td>
</tr>
<tr>
<td>BSA, m$^2$</td>
<td>1.24 ± 0.09</td>
<td>1.28 ± 0.10</td>
</tr>
</tbody>
</table>

Values are means ± SE; n, no. of subjects. REx, exercise; R, no exercise; BSA, body surface area; TBSA, total body surface area. REx and no R groups were similar in age, %TBSA burned, height, weight and BSA at 6 mo postburn. Age, height, weight, and BSA did not significantly change during the 12-wk period.

Fig. 1. Mean percent change in knee extensor peak torque, total work, and average power at 150% after 12 wk of exercise intervention. Absolute peak torque measured in newtons–meters, total work measured in joules, and average power measured in watts were used in the calculation of percent changes. REx, exercise; R, no exercise. Values are means ± SE. *$P < 0.05$ for 6- to 9-mo percent change. †$P < 0.05$ for comparison of percent change between REx and R groups.

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Measurement of total LBM obtained by DXA revealed a mean increase of 6.40% in the REx group after 12 wk of training (Fig. 2). In contrast, the mean total LBM from 6 to 9 mo in the R group remained relatively unchanged. Segmental analysis of LBM mass is presented in Table 3. All changes in segmental LBM, except arms LBM (from 6 to 9 mo) of the REx group were significantly increased compared with the changes in segmental LBM in the R group after 12 wk. Over the course of the study, two of the REx and two of the R patients were not able to participate in the DXA scan because of technical difficulties or missed appointments.

The mean percent change in treadmill time during the standardized graded exercise test was significantly greater in the REx group (57.8 ± 27.0%) vs. the R group (8.60 ± 8.00%). In addition, \( \dot{V}O_2 \) peak increased by 22.7% in the REx group compared with a decrease of 1.35% in the R group, suggesting a greater cardiovascular endurance and muscular capacity to do work (Table 3, Fig. 3).

REE was elevated (as %predicted) in both groups at the beginning of the study. However, after 12 wk, the R group increased significantly in REE by 15%, whereas the REx group’s REE remained relatively unchanged (Table 3).

**DISCUSSION**

Our results indicate that there is an increase in muscle strength, total work, and average power in the REx group after 12 wk of exercise and that this increase is not observed in the R group. In addition, there is a >20-fold difference in the mean rate of increase in total LBM in the REx vs. R group, which paralleled the increase in muscle strength, total work, and power.

To our knowledge, there are presently no published reports that have studied the effects of a resistance exercise training program in burned children. Our results are in agreement with reported strength gains in nonburned children who trained using various resistance exercise protocols. Faigenbaum et al. (8) reported improvements in strength of 13% measured with one-repetition maximum for leg extensors. Subsequently, Faigenbaum et al. (10) reported gains of 74% in strength vs. 13% in a control group as measured with 10-repetitions maximum. However, in these studies, investigators did not control for a learning effect. These increases are different than our mean increase of 44.0% (Fig. 1), but this may be due to key differences between the studies in the length of program, frequency of training, and mode of testing (isokinetic vs isotonic). More recently, Falk and Tenenbaum (11) performed a meta-analysis of studies of resistance training in children and adolescents and found three studies that failed to demonstrate significant changes in strength after intermediate (6–12 wk) or long (>15 wk) training programs. In contrast, they reported 25 studies in which strength gains were obtained. There is difficulty in comparing studies that vary in duration, intensity, and volume of training; age of participants; and types of weight-lifting equipment used. In addition, most of these studies (23 of 25) again failed to control for a learning effect. In these studies, most of the improvements in strength were between 13 and 30% as a result of resistance training.

Few articles have reported skeletal muscle hypertrophy in response to resistance training in children. Fukunaga et al. (14) showed an increase in muscle cross-sectional area of fifth graders, but not of fourth or third graders, measured by ultrasonic method. The
Table 3. Dual-energy X-ray absorptiometry, treadmill test, and resting energy expenditure results

<table>
<thead>
<tr>
<th></th>
<th>REx 6 mo</th>
<th>REx 9 mo</th>
<th>R 6 mo</th>
<th>R 9 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk LBM, g</td>
<td>14,879±1,777.3</td>
<td>15,675±1,879.2†</td>
<td>15,118±1,806.2</td>
<td>14,517±1,560.0</td>
</tr>
<tr>
<td>Leg LBM, g</td>
<td>9,225.1±1,187.7</td>
<td>9,960.6±1,274.0α</td>
<td>8,862.7±1,123.1</td>
<td>9,155.0±1,103.0α</td>
</tr>
<tr>
<td>Arm LBM, g</td>
<td>3,047±430.0</td>
<td>3,221±420.5α</td>
<td>3,089±479.1</td>
<td>3,401±602.8</td>
</tr>
<tr>
<td>Total LBM, g</td>
<td>29,045±3,562.4</td>
<td>30,649±3,748.1α</td>
<td>29,166±3,039.1</td>
<td>28,999±2,866.3</td>
</tr>
<tr>
<td>Relative VO₂peak, ml·kg⁻¹·min⁻¹</td>
<td>29.9±5.42</td>
<td>36.7±5.63†</td>
<td>29.6±2.10</td>
<td>29.2±1.40</td>
</tr>
<tr>
<td>Peak treadmill time, min</td>
<td>10.0±1.91</td>
<td>14.3±3.33†</td>
<td>12.4±0.70</td>
<td>13.9±1.10</td>
</tr>
<tr>
<td>REE</td>
<td>kcal/day</td>
<td>% predicted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,455±66.30</td>
<td>119.4±5.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,533±94.6</td>
<td>118.8±3.40</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1,487±144.3</td>
<td>108.3±8.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,707±172.5α</td>
<td>120.4±8.90α</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are means ± SE. LBM, lean body mass. Head LBM is not reported, but is part of total LBM. Resting energy expenditure (REE) increased significantly in the R group, whereas it remained relatively unchanged in the REx group. However, REE for both groups remained elevated as a percent of predicted (119% for REx and 120% for R) by the Harris-Benedict equation (27), indicating a persistent hypermetabolic state. *Significant change within a group from 6 to 9 mo, P < 0.05. †Significant difference in % change after 12 wk between REx and R groups, P < 0.05.

mean age of their fifth-grade subjects was 11.0 yr. Another study, by Mersh and Stoboy (26), showed an increase in quadriceps cross-sectional area determined by nuclear magnetic resonance imaging in two prepubertal monozygous twin boys. On the other hand, Vrijens (38) failed to show a significant effect of 20 wk of weight training on either arm or midthigh lean cross-sectional area, despite increases in strength. Our results agree with those of Fukunaga et al. (14) and Mersh and Stoboy (26). We report that resistance training increased total energy expenditure (REE) significantly by 15±4.9% after 12 wk in the R group vs. 6±4.9% in the REx group. Levels of REE expressed as percent predicted, calculated using the Harris-Benedict equation (27), remained relatively unchanged, although they were still elevated in the REx group (119.4–118.8%). In contrast, in the R group, REE (%predicted) significantly increased from 108.3 to 120.4%. The fact that the REx patients show no further increase in REE over time may indicate that exercise may have sympathetic-attenuating effects such as those demonstrated by Peronnet et al. (33) and O’Sullivan and Bell (29). Both Peronnet et al. and O’Sullivan and Bell reported that physical training had sympathetic activity lowering effects. On the other hand, Hunter et al. (22) reported that resistance training increased total energy expenditure in older adults. However, in that study, individuals trained exclusively with resistance exercises. Therefore, a combination of resistance and
aerobic exercise training may be needed to produce a balanced effect between increasing or decreasing sympathetic activity.

The normal physiological response to resistance training is reported to be increased neural activation and muscle hypertrophy (30, 35). It is believed that neural adaptation predominates in the early phase of training and hypertrophy in the later phase. This could explain the modest increase in total LBM observed in the REx group. Segmental analysis of total LBM showed a significant increase in training trunk, legs, and arms of the children participating in exercise. Comparison between REx and R groups revealed a significant difference in total and trunk LBM, although leg and arm LBM failed to achieve statistical significance ($P = 0.11$ and $P = 0.99$, respectively). Despite increases in strength, total work, power, and total LBM found in our study, muscle weakness seems to persist, as reflected by the lower absolute peak torque values compared with children of similar age, height, and weight and at a comparable isometric degree of leg extension (Table 4) (35).

One possibility for the persistent relative muscle weakness is that the exercise stimulus or intensity of our program was not enough to elicit muscular strength changes. However, an extensive review of the literature (5, 9, 11) and guidelines (1–3, 16) for resistance training programs in healthy and other nonburn populations suggests that a broad range exists (4–20 wk of strength training) to demonstrate strength gains. Clearly, our 12-wk training program falls within the range of suggested duration of training programs. A second possibility for the persistent relative muscle weakness is the potential for resistance training to increase muscle breakdown in an already compromised state. Evans and Cannon (7), in a review on “exercise-induced muscle damage,” cite references reporting that, in both humans and rats, exercise elicits increases in circulating creatine kinase, which is typically associated with “muscle damage.” No measures that reflect muscle breakdown (such as levels of urinary creatine) were performed in our study, so we cannot address such issue at this time. Perhaps, 48 h between bouts of exercise is not enough recovery time to allow muscle protein synthesis in our patient population.

We initiated the exercise program at 6 mo postburn on the basis of the 25 yr of clinical experience of the surgeons and the interdisciplinary team at our institution. At 6 mo postinjury, the majority of pediatric patients with burns on >40% of their body surface are 95% healed, are ambulatory, and have had the opportunity to return home, placing them in a more favorable psychological disposition for another long-term regimen (e.g., 12 wk). It is not known at this time whether the time period of 6–9 mo postburn is a better time period to initiate an exercise training program. A study comparing 12 wk (or longer) of training at 9–12 mo post-burn injury could help answer these questions.

Presently, there are no studies that have reported on the changes in quality of life measures due to an exercise program in burned children. Sheridan et al. (36) reported that 20% of 85 patients (<18 yr of age at time of burn) evaluated on long-term physical functioning after massive burns were >2 SD below the nonburn norm, indicating a continued physical disability. However, the population norm used in their study was ages 18–25 yr. In addition, they assessed physical functioning only by questionnaire, which was given an average of 14.7 ± 6 yr after the burn injury. Most importantly, no effects of exercise or an exercise program was assessed. A few studies on adults have addressed factors related to the return to work after burn injury (6, 40, 41), but they did not involve exercise.

Our results show a significantly greater increase in functional physical performance such as strength, power, and total work due to exercise training. An increase in muscle strength and ability to do work should result in an improvement in the burned child’s capability to return to normal activities of daily living, in addition to increased emotional and physical independence and self-confidence. However, the association between physical status and emotional and physical independence in burned children is presently unknown.

![Table 4. Demographic characteristics and isometric peak torque test results of a subgroup of patients](jap.org)
Additional physical outcomes resulting from the exercise program are reflected in the duration on the treadmill and in changes in \( V\text{O}_2\text{peak} \). The REx group lasted significantly longer and had higher \( V\text{O}_2\text{peak} \), reflecting a higher cardiovascular endurance than the R group (Fig. 3, Table 3). Parker et al. (31) reported, in older adults, improvements in endurance time after resistance training despite no changes in \( V\text{O}_2\text{peak} \). We believe that the improvement in treadmill time in the REx group is due to an increased capacity of skeletal muscle to perform oxidative work and handle anaerobic metabolic loads during maximal and near-maximal exercise. Further studies are needed to elucidate the mechanisms by which cardiovascular endurance and the muscle’s capacity to do work are increased. Another possibility for the improvement in treadmill time could be partially due to an improvement in motivation or psychological factors that are a well-known benefit of exercise (4, 13, 28). It is impossible to discern this psychological potential contribution of exercise at this point in time. However, it would be an additional benefit that would be greatly welcomed in the long-term rehabilitation of children with burn injury.

We utilized exercise as a way to prevent or attenuate further deterioration of muscle catabolism seen in burned patients. Our results indicate that, in children with >40% TBSA burned, an exercise program that is individualized, based on progressive resistance, and complemented with endurance training is successful in improving strength, power, the muscle’s capacity for work, and aerobic capacity. Given the improved, but still compromised, muscle strength and endurance found in the present study in these patients, more mechanistic studies on the effect of exercise and how exercise may benefit victims of burn injury are needed. Finally, our results demonstrate that severely burned children gain muscle strength by participating in an exercise program and that such a program should be a fundamental component of multidisciplinary outpatient treatment for victims of thermal injury.

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