

Augmented Exercise in the Treatment of Deconditioning From Major Burn Injury

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ABSTRACT. de Lateur BJ, Magyar-Russell G, Bresnick MG, Bernier FA, Ober MS, Krabak BJ, Ware L, Hayes MP, Fauerbach JA. Augmented exercise in the treatment of deconditioning from major burn injury. *Arch Phys Med Rehabil* 2007;88(12 Suppl 2):S18-23.

Objective: To investigate the efficacy of a 12-week exercise program in producing greater improvement in aerobic capacity in adult burn survivors, relative to usual care.

Design: Randomized, controlled, double-blinded trial.

Setting: Burn center.

Participants: A population-based sample of 35 adult patients admitted to a burn center for treatment of a serious burn injury.

Intervention: A 12-week, 36-session, aerobic treadmill exercise program where work to quota (WTQ) participants intensified their exercise according to preset quotas and work to tolerance (WTT) participants continued to their tolerance. Participants completed a maximal stress test at baseline and 12 weeks to measure physical fitness.

Main Outcome Measure: Maximal aerobic capacity.

Results: The WTT and the WTQ exercise groups both made significant improvements in aerobic capacity from baseline to 12 weeks ($t = -3.60$, $P \leq .01$; $t = -3.17$, $P \leq .01$, respectively). The control group did not ($t = -1.39$, $P = .19$). WTT and WTQ participants demonstrated significantly greater improvements in aerobic capacity in comparison to the control group members ($F = 4.6$, $P \leq .05$). The WTT and WTQ groups did not differ significantly from each other with regard to their respective improvements in aerobic capacity ($F = .014$, $P = .907$).

Conclusions: The aerobic capacity of adult burn survivors can be improved with participation in a structured, 12-week exercise program after injury.

Key Words: Aerobic exercise; Burns; Cardiovascular deconditioning; Exercise; Rehabilitation.

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SURVIVAL RATES AFTER severe burn injury have significantly improved in the past 2 decades.^{1,2} This progressive decline in mortality has highlighted the importance of physical rehabilitation after burn injury to maximize the recovery of physical function. Typically, standard physical and occupational rehabilitation therapy targets the improvement of overt physical changes associated with burn injury, such as uncomfortable scarring, range of motion (ROM) limitations, and contractures.³ A recent study⁴ found, however, that independence in locomotion was the single variable that discriminated between patients who went home after discharge from those who were discharged to another institution. Thus, factors affecting locomotion, such as fatigue and muscle deconditioning, are also important during the rehabilitation phase of burn recovery.

There are at least 2 major factors that contribute to muscle deconditioning after major burn injury: bedrest and catabolic processes that lead to muscle atrophy. A serious burn injury results in the greatest hypermetabolic response in comparison with other physical traumas.⁵ This increased metabolic rate can persist until wound closure is achieved⁶ and perhaps for 6 to 9 months after wound closure.⁷ Prolonged states of hypermetabolism result in catabolic consequences that may not be recognized in the acute phase of the injury but can later cause significant muscle wasting and deconditioning.

With the overall increase in survival rates from serious burns, loss of lean body mass (LBM) and decreased aerobic capacity are being recognized as common sequelae of serious burn injury that can impair wound healing, raise the risk of infection, and ultimately increase the likelihood of burn-associated morbidity or mortality.⁸ In a recent investigation,⁹ people with smaller burns did not differ with respect to muscle strength from a nonburned control group matched for age, sex, body mass index, and physical activity level. People with burns of 30% total-body surface area (TBSA) or larger produced significantly less torque, work, and power in the quadriceps than control subjects. The ability to develop muscle power at the elbow was also compromised in subjects with severe burn injuries.

Prevention and treatment of deconditioning and muscle wasting are emerging as important areas for research in burn rehabilitation. Exercise has been shown to counteract the muscle-wasting effects of age and inactivity.¹⁰⁻¹² A recent review¹³ of the evidence in burn rehabilitation did not find any published controlled investigations of the effectiveness of aerobic exercise intervention in adult burn survivors. However, Celis¹⁴ and Suman¹⁵ and colleagues have examined the effects of exercise in children with thermal injury. Celis found that exercise and physiotherapy programs significantly decreased the likelihood of having to have surgery to release burn scar contractures, and Suman reported a significant improvement in muscle strength, power, and LBM relative to a standard rehabilitation program without exercise. Hart et al⁸ further emphasized the need for rehabilitation efforts to combat catabolism and concluded that

sepsis and excessive hypermetabolism are associated with muscle catabolism.

Fordyce et al¹⁶⁻²¹ observed that patients with chronic pain of various etiologies were often deconditioned and experienced pacing challenges during rehabilitation as they attempted to increase activity levels. During periods of reduced pain, patients tended to overexert themselves physically and would then experience a subsequent increase in pain and an inability or unwillingness to engage in their usual levels of activity. In an effort to better help chronic pain patients through physical recovery, Fordyce and his team advise physical therapists to have patients perform a quantifiable activity (eg, walking laps) to their tolerance (work-to-tolerance [WTT]) and then determine an individualized, gradual, quota increase based on their baseline performance (work-to-quota [WTQ]). Patients should then be instructed to perform only at quota. According to Fordyce, after the WTQ system is initiated, patients are more likely to progress without major setbacks from increased pain and to obtain positive reinforcement through their gradual increase in activity levels.¹⁶ Ehde et al²² adapted the quota system in a patient with severe burns who displayed signs of passivity, learned helplessness, and depressive symptomatology, which the authors proposed contributed to decreased participation in physical therapies (ie, walking, ROM exercises, pressure garment use, splint use). Their results suggest that quota-guided exercise was successful in mitigating a sense of learned helplessness and in increasing that patient's participation in rehabilitative therapies. Similar to chronic pain patients, survivors of serious burn injury often display symptoms of learned helplessness, deconditioning, and rehabilitation challenges, yet the literature has not compared the efficacy of WTT and WTQ exercise programs in improving adherence to therapies and, consequently, aerobic capacity in burn patients.

Our objective in this double-blinded, randomized, controlled trial was to test whether an early exercise intervention, combined with the usual and customary care, hastens aerobic capacity recovery in adults with major burn injuries. The exercise intervention was a structured, 12-week program of aerobic training designed to promote return to fitness, prevent prolonged aerobic deconditioning, and compare the efficacy of a WTQ with a WTT program (both compared with a control group). The training was performed 3 times a week. Based on clinical research with chronic pain patients, we hypothesized that burn-injured patients on the WTQ schedule, relative to patients in the WTT group and the control group, would recover greater aerobic capacity because of the gradual and consistent increase in aerobic training over the 12 weeks.

METHODS

Participants

Participants were recruited from among adult patients admitted to the Johns Hopkins Burn Center in Baltimore, from September 1999 to May 2006. Criteria for participation were that the patient (1) sustained a burn injury serious enough to require hospitalization, (2) was at least 18 years of age, (3) was English-speaking, and (4) had the capacity to undergo consent procedures as outlined by the Johns Hopkins University Institutional Review Board. Patients were excluded if they were unable to provide informed consent because of cognitive impairment (eg, delirium, psychosis, Mini-Mental State Examination score <23/30), or if they had had any cardiac insult within the past 6 months involving myocardial infarction (MI), unstable angina, congestive heart failure, or pacemaker placement (American College of Sports Medicine [ACSM] criteria for early termination of a stress test including acute MI, moderate-to-severe angina, drop in systolic blood pressure, serious arrhythmias [second- or third-degree arteriovenous block,

sustained ventricular ectopic beats], electrocardiographic changes from baseline greater than 2mm ST depression or elevation, or increasing chest pain).²³ The number of eligible patients who either were not approached for participation or chose not to participate was not recorded during the lengthy recruitment period.

Study Design

Subjects were randomly assigned to 1 of 3 groups: standard functional restoration (SFR; control group), WTQ, or WTT. A randomized sequence was generated by Excel^a (no restrictions) to ensure random allocation of participants. The sequence was concealed from consent-designee research staff using an electronic password-protected document. A project instructor (GM-R) generated and protected the randomized sequence; participants were recruited and consented by the research project coordinator (MGB), and the instructor (GM-R) then assigned participants to their groups according to the randomized sequence. The SFR protocol is the standardized burn rehabilitation protocol tailored to the needs of each patient at the Johns Hopkins Burn Center. It includes such therapies as ROM, massage, splinting, stretching, strengthening, and functional training for ambulation and activities of daily living (ADLs). SFR group participants underwent maximal aerobic capacity ($\dot{V}O_2\text{max}$) stress tests at baseline and at 12 weeks. Additionally, these participants were examined biweekly throughout the intervention by a physical or occupational therapist, who measured quadriceps and hamstring strength, pinch and grip strength, active ROM at all affected burn joints, and self-selected walking speed. Participants and a supervising physician (BJD) who assessed the outcomes of the stress tests were blinded to group assignments.

All participants received SFR; participants in the WTQ and WTT were required to augment their usual care by adhering to a treadmill ambulation schedule. After the baseline cardiovascular stress test, subjects in the WTT and WTQ groups participated in treadmill exercise sessions 3 times a week throughout the 12-week protocol. Participants' target exercise heart rates were calculated according to their age-predicted maximal heart rate and their maximal stress heart rate, which was recorded during the initial stress test. The target exercise heart rate was calculated as 60% of the participant's heart rate reserve (maximal exertion). WTQ participants gradually intensified their exercise program by increasing their target exercise heart rate and time according to preset quotas, whereas WTT participants were instructed to tolerate the aerobic exercise at their target heart rate for as long as possible. All exercise sessions were capped at 30 minutes.

Exercise Testing

Maximal aerobic capacity ($\dot{V}O_2\text{max}$) tests were conducted at the Johns Hopkins Bayview General Clinical Research Center's Exercise and Body Composition Lab. The testing process was explained to the subjects on their arrival for each test. A brief medical history and resting 12-lead electrocardiograph were reviewed before they were permitted to begin the test.

We used a modified BRUCE protocol²⁴ at each assessment. The BRUCE protocol is accepted by ACSM²³ as standard procedure for ambulatory stress testing and is based on the seminal work of cardiologist Robert Bruce in the early 1970s.²³ The modified workload began at 2.7km (1.7mph), 0% grade and was increased every 3 minutes at 1.7 mph to 5% grade and 1.7 mph, 10% grade before the conventional BRUCE protocol was begun. We used this multistage protocol because of the limited functional capacity of burn survivors; it does not expose subjects to large and

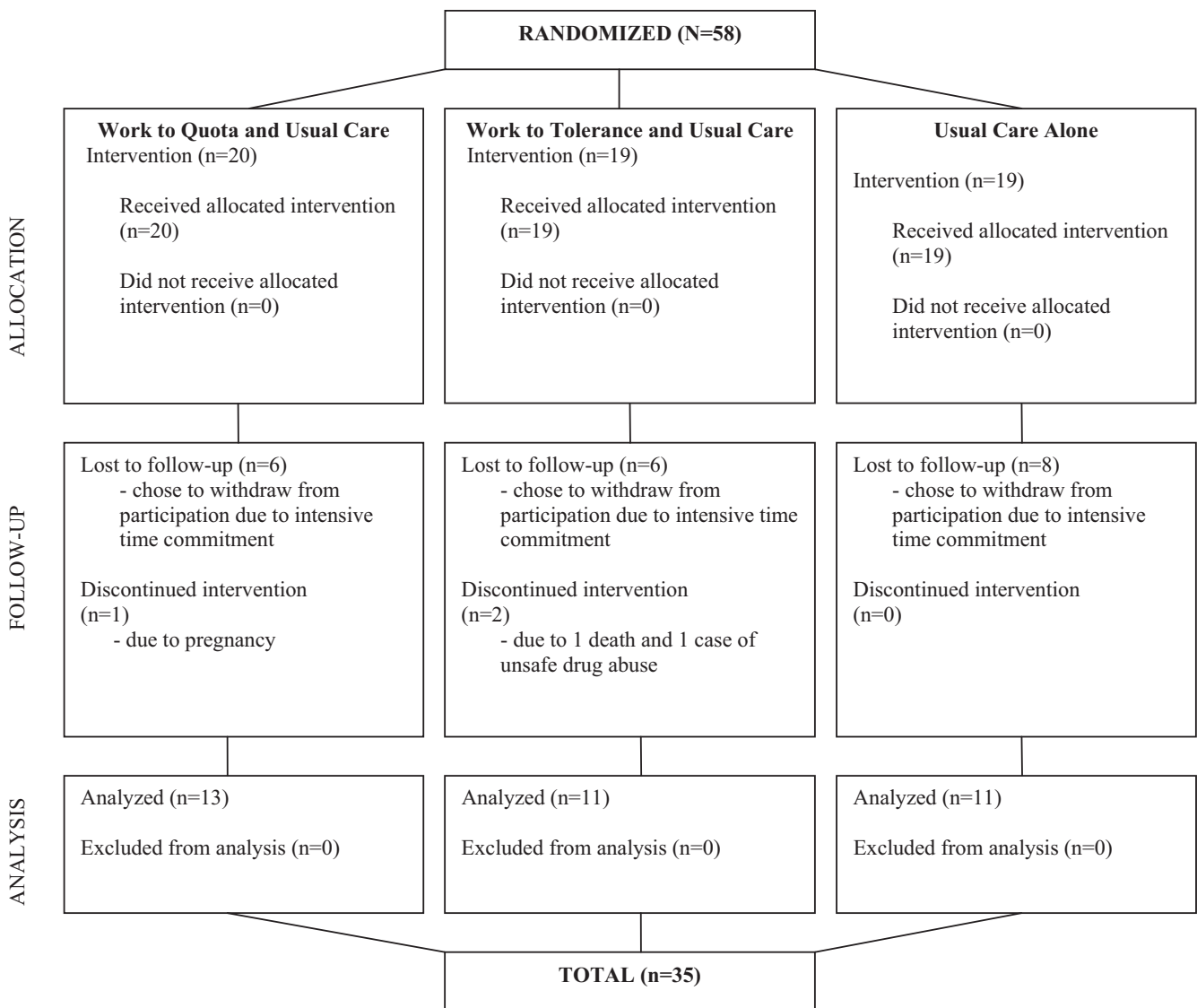


Fig 1. Augmented exercise program randomized control trial CONSORT flowchart.

unequal increments in workload.²³ A 30-second sample of resting gases was collected before subjects began the 30-second warm-up period at 1.6km (1.0mph). Blood pressure measurements were taken with a manual mercury sphygmomanometer every 3 minutes, concurrent with the end of each stage. Electrocardiographic and heart rate activity were continually monitored throughout the test. Subjects graded their overall body exertion using the Borg ratings of perceived exertion scale²⁵ at the end of each stage of the protocol.

The subjects were given verbal encouragement during the test. They were instructed to exercise until they reached a level of maximal overall body fatigue. To facilitate a true measurement of their maximal exercise capacity, they were discouraged from leaning on the treadmill's handrails. The test continued until the patient was exhausted, or until there were apparent indications for terminating the test.²³ Heart rate, blood pressure, and electrocardiographic activity were monitored during exercise and recovery until they returned close to resting levels.

The primary outcome measure of aerobic capacity was the participants' $\dot{V}O_{2max}$. Respiratory gas analysis was performed

and oxygen uptake ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), and respiratory quotient were measured using the SensorMedics Vmax 229 metabolic system.^b $\dot{V}O_{2max}$ was calculated by averaging the computer-selected "peak zone," which was the last 30 seconds of the final stage. The anaerobic threshold was determined using the V-slope technique,²⁶ which is a component of the Vmax 229 software. These results were then confirmed by graphs that plotted $\dot{V}CO_2$ as a function of $\dot{V}O_2$. This plot created 2 lines intersecting where metabolic acidosis occurs, determining the $\dot{V}O_{2max}$.

RESULTS

Descriptive Data

Sample characteristics. The total sample included 35 participants who completed all 12 weeks of the exercise program, as indicated by baseline and postintervention cardiovascular stress tests. Figure 1 illustrates the flow of participants through each stage of the study. The average number of days \pm standard deviation (SD) between the subjects' burn injury and the

Table 1: Group Demographic Characteristics

Group	N	Mean Age \pm SD (y)	Sex (% male)	Mean TBSA \pm SD (%)	Burn Type (% of population)	Percentage Employed at Time of Burn
All groups	35	38.0 \pm 13.3	74	19.3 \pm 15.7	Flame: 60 Scald: 28 Electrical: 9 Chemical: 3	77
SFR	11	34.9 \pm 14.5	82	21.6 \pm 19.4	Flame: 73 Scald: 27	64
WTT + SFR	11	43.5 \pm 8.9	91	16.8 \pm 9.8	Flame: 46 Scald: 36 Electrical: 9 Chemical: 9	73
WTQ + SFR	13	35.4 \pm 14.8	54	19.5 \pm 17.2	Flame: 62 Scald: 23 Electrical: 15	92

start of their participation in the study was 37.5 \pm 23.3 (range, 9–122). There were no significant differences in sex (Pearson χ^2 test=1.79, $P=.41$), age ($t=1.26$, $P=.21$), employment status (Pearson χ^2 test=3.40, $P=.33$), type of burn injury (Pearson χ^2 test=6.2, $P=.29$), or TBSA burned ($t=-.99$, $P=.33$). Also, there were no significant differences between participants who completed the study protocol (completers; $n=35/58$ [60%]) and participants who agreed to participate but did not complete the protocol (noncompleters; $n=23/58$ [40%]). Sex, age, type of burn injury, average TBSA, and employment status for completers are presented in table 1. Among the completers, there were no significant differences in TBSA ($F=.24$, $P=.79$), type of burn injury (Pearson χ^2 test=4.90, $P=.557$), age ($F=1.26$, $P=.30$), or weight ($F=.94$, $P=.40$) between treatment groups at baseline. Group differences in sex were not significant (Pearson χ^2 test=4.76, $P=.09$).

Treatment Effects

Physiologic characteristics. Tables 2 and 3 show the sample and group averages for physiologic variables collected during the baseline and post-test cardiovascular stress tests. There were no significant differences at baseline between group members in weight ($F=.87$, $P=.43$), resting heart rate ($F=.34$, $P=.72$), maximum heart rate ($F=1.95$, $P=.16$), and absolute $\dot{V}O_2$ ($F=.68$, $P=.51$). Likewise, there were no significant differences between groups at the 12-week post-test in weight ($F=.20$, $P=.82$), resting heart rate ($F=.25$, $P=.78$), maximum heart rate ($F=.31$, $P=.73$), and absolute $\dot{V}O_2$ ($F=.07$, $P=.93$).

Within-group effects. Over the course of the exercise program (from baseline to post-test assessment periods), WTQ ($t=-3.60$, $P\leq.01$) and WTT ($t=-3.17$, $P\leq.01$) groups displayed significant improvement in aerobic capacity, as mea-

sured by $\dot{V}O_{2max}$. The SFR group did not show significant improvement in aerobic capacity ($t=-1.39$, $P=.19$) (fig 2).

Between-group effects. WTQ and WTT participants demonstrated significantly greater improvements in aerobic capacity, as measured by $\dot{V}O_{2max}$, in comparison with the SFR group ($F=4.6$, $P\leq.05$). The WTQ and WTT group members' improvements in aerobic capacity did not differ significantly from each other ($F=.014$, $P=.907$).

DISCUSSION

This study demonstrates for the first time in adult burn patients that aerobic conditioning in combination with standard functional restoration therapy is superior to standard functional restoration alone. Although the 2 experimental exercise treatment groups appeared slightly less fit than the control group at baseline, this difference was not statistically significant. Additionally, both groups taking part in the experimental exercise treatment improved dramatically during the study, crossing over the line of progression of the SFR group, which did not show significant improvement in aerobic capacity.

Aerobic capacity is an important aspect of burn rehabilitation. By participating in the treadmill-walking program, the WTT and WTQ subjects significantly increased their $\dot{V}O_{2max}$. Thus, burn survivors who participate in a regular exercise routine are more likely to realize health-related benefits such as improved flexibility, balance, stamina, and muscular strength,²⁷ all of which are crucial in returning to an active and independent lifestyle. Physical activity has several additional potential benefits, such as decreased anxiety and depression and enhanced feelings of well-being²⁷ resulting from the release of endorphins secreted during muscular activity, as well as through other mechanisms.

Table 2: Baseline Group Stress Test Statistics

Group	N	Mean Weight \pm SD (kg)	Mean Resting Heart Rate \pm SD (bpm)	Mean Maximum Heart Rate \pm SD (bpm)	Mean $\dot{V}O_{2max}$ \pm SD	Absolute $\dot{V}O_2$
All groups	35	82.2 \pm 20.4	85.3 \pm 15.6	163.2 \pm 22.1	21.7 \pm 7.0	1809.0 \pm 687.5*
SFR	11	88.0 \pm 20.9	84.6 \pm 15.8	167.6 \pm 20.9	23.2 \pm 8.6	1993.7 \pm 865.3
WTT + SFR	11	82.9 \pm 17.2	88.5 \pm 15.5	152.5 \pm 24.3	21.2 \pm 5.8	1787.4 \pm 611.8
WTQ + SFR	13	76.6 \pm 22.5	83.1 \pm 16.3	168.5 \pm 19.5	20.8 \pm 6.7	1659.5 \pm 581.2†

*Based on 34 participants.

†Based on 12 participants.

Table 3: Group Stress Test Statistics Post-Test

Group	N	Mean Weight \pm SD (kg)	Mean Resting Heart Rate \pm SD (bpm)	Mean Maximum Heart Rate \pm SD (bpm)	Mean $\dot{V}O_{2max} \pm$ SD	Absolute $\dot{V}O_2$
All groups	35	85.8 \pm 23.6	79.8 \pm 14.7	168.4 \pm 17.6	25.7 \pm 6.1	2215.3 \pm 647.7*
SFR	11	89.6 \pm 30.3	77.5 \pm 9.6	171.2 \pm 18.6	24.7 \pm 7.3	2215.1 \pm 750.6
WTT + SFR	11	86.1 \pm 17.9	80.9 \pm 15.1	165.2 \pm 17.9	26.5 \pm 4.3	2269.3.4 \pm 533.6
WTQ + SFR	13	82.5 \pm 22.9	80.9 \pm 18.3	168.9 \pm 17.3	25.8 \pm 6.6	2166.0 \pm 694.3 [†]

*Based on 34 participants.

[†]Based on 12 participants.

Results of this study suggest that without aerobic exercise, deconditioned burn survivors will not achieve the same gains in aerobic capacity as patients who participate in an exercise-training program. Moreover, a decrease in cardiorespiratory fitness is a health-related concern for all people, whether or not they have a major burn injury; low levels of fitness are associated with a markedly increased risk of premature death from any number of causes, but specifically from cardiovascular disease.²⁸ Additionally, when movement and exercise are limited, ROM can be diminished, which often causes muscular and joint contractures and a decrease in quality of life among burn survivors.

The fact that WTT and WTQ groups did not differ from each other after training suggests that the quotas may have been set too conservatively (ie, too low) for the WTQ subjects, or that the subjects in the WTT group may have exerted themselves more than was anticipated a priori. We set the quotas conservatively because of concerns expressed by institutional review committees that vigorous exercise might aggravate the hypermetabolic state of these patients. Additionally, it is reasonable to be concerned that temperature regulation might be problematic in patients with burn injuries (hence limiting the utility of an aerobic exercise program). McEntire et al²⁹ found, however, that exercise at moderate intensities conducted for 20 minutes at room temperature was safe in children with up to 75% of TBSA burns. Similarly, in this study there was no evidence that exercise was unsafe for participants during protocol training sessions or during maximal stress testing. Specifically, if aerobic training exacerbated hypermetabolism, it would be ex-

pected that chest discomfort, shortness of breath, or palpitations would have resulted in either the participant or the physician stopping the exercise session early. Chest pain, dyspnea, and tachycardia were not limiting factors in the stress tests, however. To the contrary, and perhaps not surprisingly given the muscle wasting and deconditioning in these patients, leg discomfort or leg muscle fatigue were the most common limiting factors. It should be noted that for safety purposes, a physician (BJD or BJK) was present throughout every treadmill test.

Study Limitations

Limitations of this study include the relatively small total sample size. The findings were so robust, however, that we believe concerns about the sample size are partially negated. Another concern is that patients with burns of all sizes and severity were permitted to participate. Again, however, the effect sizes were robust even among subjects with smaller and less severe burns who were likely to have lost less muscle mass and aerobic capacity during hospitalization. This suggests that the exercise programs may have even more relevance for people with more serious burn injuries (eg, burns involving more than 30% of TBSA, inhalational injury, amputations). Another potential limitation is that subjects were recruited from only 1 regional burn center, thereby limiting generalizability.

A final concern is the disproportionate manner in which results may have been affected by sex differences in group membership. Recent evidence suggests that women and men generally differ in their metabolic responses to incremental exercise,³⁰ and that sex differences in pulmonary function and exercise capacity limit aerobic capacity and exercise tolerance in women.³¹ Such findings suggest that in future investigations, it would be reasonable to control for potential confounders by stratifying the treatment groups according to sex during randomization.

CONCLUSIONS

Our results show that a moderate, 30-minute treadmill walking program performed 3 times a week for 12 weeks, whether patient-limited or experimenter-limited, combined with customary postburn care, significantly improves aerobic fitness, whereas customary care alone does not. Important directions for further research include conducting trials with greater numbers of participants and more intensive exercise protocols that allow for comparison of the effectiveness of differing exercise programs for adult burn survivors. It is also important to investigate alternative therapies that might achieve the same benefits. For instance, in a placebo-controlled, randomized trial with severely burned children, the administration of growth hormone from hospital discharge to 12 months postburn significantly improved the height, weight, LBM, bone mineral content, cardiac function, and muscle strength of children in the

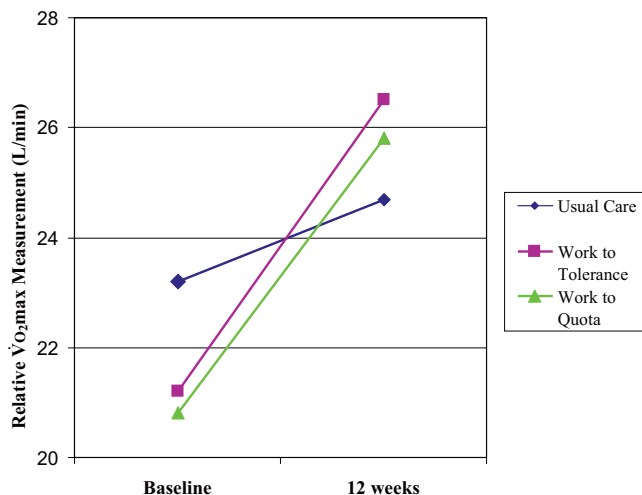


Fig 2. Measure of $\dot{V}O_{2max}$ at baseline and at 12 weeks for the 3 study groups.

treatment group compared with children who received a placebo.³² Future research should attempt to replicate these results with adults to discern whether the effects are generalizable to an adult burn population. Another avenue for investigation is an analysis of the relation between aerobic capacity and burn-specific functional outcomes, such as the ability to return to previous employment, perform ADLs, live independently, and regulate body temperature. Finally, clinical implications from this study suggest that rehabilitation professionals should consider including aerobic training in physical therapy regimens to provide patients with unique physiologic benefits in recovering from burn injury.

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Suppliers

- a. Microsoft Corp, One Microsoft Way, Redmond, WA 98052.
- b. SensorMedics Corp, 22745 Savi Ranch Pkwy, Yorba Linda, CA 92887.