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Cardiorespiratory Capacity and Strength Remain Attenuated in Children with Severe Burn Injuries at Over 3 Years Postburn

Janos Cambiaso-Daniel, MD[1,2,3,*], Eric Rivas, PhD[1,2,4,*], Joshua S. Carson, MD[5], Gabriel Hundeshagen, MD[1,2,6], Omar Nunez Lopez, MD[1,2], Shauna Q. Glover, MA[1,2], David N. Herndon, MD[1,2], and Oscar E. Suman, PhD[1,2]

Objectives To compare physical capacity and body composition between children with burn injuries at approximately 4 years postburn and healthy, fit children.

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

Results At discharge, lean body mass was 89% of that in children without burn injuries, and exercise rehabilitation restored this to 94% ($P < .01$). At 3.5 years postburn, lean body mass (94%), bone mineral content (89%), and bone mineral density (93%; each $P \leq .02$) remained reduced, whereas total body fat was increased (148%, $P = .01$). Cardiorespiratory fitness remained lower in children with burn injuries both after exercise training (75%; $P < .0001$) and 3.5 years later (87%; $P < .001$). Peak torque (60%; $P < .0001$) and average power output (58%; $P < .0001$) were lower after discharge. Although exercise training improved these, they failed to reach levels achieved in healthy children without burns (83-84%; $P < .0001$) but were maintained at 85% and 82%, respectively, 3.5 years later ($P < .0001$).

Conclusions Although the benefits of rehabilitative exercise training on strength and cardiorespiratory capacity are maintained at almost 4 years postburn, they are not restored fully 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. *(J Pediatr 2018;192:152-8).*

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 (LBM), 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 elevated significantly in pediatric patients with burn injuries compared with age-matched control patients for up to 2 years postburn.[6] Similarly, Hart et al found that rates of muscle breakdown also remain greater than normal more than a year after the injury.[7] Persistent catabolism particularly is 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 recovery from burn injuries.[14-17]

Although significant improvements in short-term outcomes have been well documented with modern burn care and rehabilitative exercise programs, the lasting

LBM	Lean body mass
VO_2	Oxygen consumption

From the [1]Department of Surgery; [2]Shriners Hospital for Children, University of Texas Medical Branch, Galveston, TX; [3]Division of Plastic, Aesthetic and Reconstructive Surgery, Department of Surgery, Medical University of Graz, Graz, Austria; [4]Department of Kinesiology & Sport Management, Texas Tech University, Lubbock, TX; [5]Shands Burn Center, Department of Surgery, University of Florida, Gainesville, FL; and [6]BG Trauma & Burn Center, Department of Hand, Plastic and Reconstructive Surgery, University of Heidelberg, Ludwigshafen, Germany

*Contributed equally.

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effects of these (beyond 2 years) are unknown. To determine whether rehabilitation programs are needed beyond 2 years postburn, we compared physical capacity and body composition in children with severe burn injuries at up to 3.5 years postburn with those in healthy age- and sex-matched children without burn injuries.

Materials and Methods

This was a retrospective case control study with controls matched by age and sex. On admission to our institution, pediatric patients underwent standard of care treatment involving reconstructive surgery and skin grafting. They then were 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. 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 3-4 years postburn compared with healthy control patients.

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 (Galveston, Texas). 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 nonthermal 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 36-48 months' postburn.

To control for sex as well as growth and development over 3.5 years, we matched each child with burn injuries by age and sex to 2 separate controls: one for the discharge and postexercise 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 publicly 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 mL $O_2 \cdot kg^{-1}\ min^{-1}$. In addition, all control subjects were considered to have fair-to-excellent VO_2 (male: 38-45 mL $O_2 \cdot kg^{-1}\ min^{-1}$; female: 39-42 mL $O_2 \cdot kg^{-1}\ min^{-1}$) according to norms for children aged 13-19 years reported by the Cooper Institute for Aerobics Research.[18] Each healthy-fit child was matched to each patient with burn injuries for sex and age. For all study patients and control subjects,

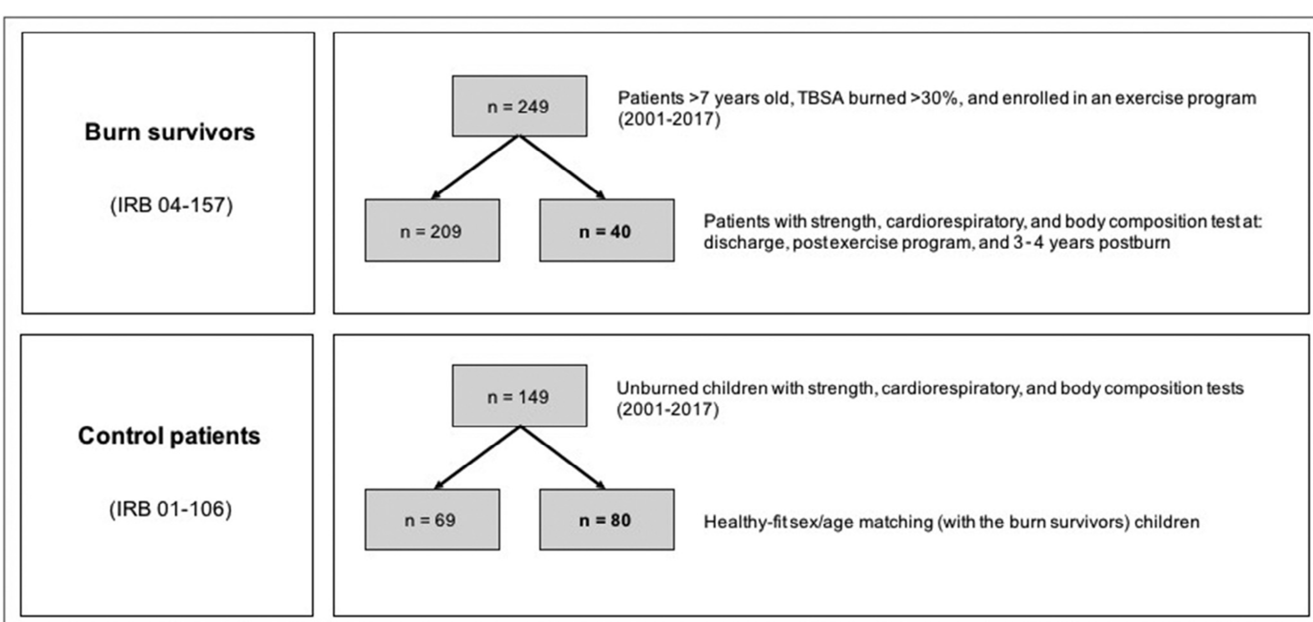

Figure 1. Patient flow diagram. *IRB*, institution review board; *TBSA*, total body surface area.