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THE NIDRR BURN INJURY REHABILITATION MODEL SYSTEM PROGRAM: SELECTED FINDINGS

Sponsored by the American Congress of Rehabilitation Medicine as a Supplement to the Archives of Physical Medicine and Rehabilitation

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A SPECIAL THANKS TO MEMBERS OF THE ACRM ARCHIVES SUPPLEMENT COMMITTEE AND REVIEWERS FOR THEIR CONTRIBUTIONS TO THIS SUPPLEMENT
INTRODUCTION

The NIDRR Burn Injury Rehabilitation Model System Program: Selected Findings

David R. Patterson, PhD


The quality of burn care has improved over the past few decades, and consequently many more survivors with large-area burn injuries have long-term rehabilitation needs. The National Institute on Disability Rehabilitation Research recognized that the rehabilitation of people with burn injuries has been underaddressed and established model systems of care for this population in 1994. This special supplement to the Archives of Physical Medicine and Rehabilitation reports on some of the research that has been generated by the Burn Rehabilitation Model Systems over the past 13 years.

Key Words: Burns; Rehabilitation.

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Burn injuries have largely been neglected as etiologies for disability in the literature. However, several developments have raised awareness of burn trauma as a source of acquired disability that often requires rehabilitation. A primary trend is the increase in survival rates for people with severe burn injuries. The percentage of people who survive with very large burn injuries has increased dramatically over the past few decades.1-3 Another development is the increased recognition that rehabilitation for burn-related disability should extend beyond strengthening and mobility to address the cosmetic disfigurement often experienced by burn survivors, as well as related pain and stress disorders. A further important step was recognition by the National Institute on Disability and Rehabilitation Research (NIDRR) that the rehabilitation issues faced by burn survivors were significant enough to warrant creation of a model system worthy of research funding. NIDRR’s action was undoubtedly a reaction to a growing recognition for rehabilitation efforts needed for burn injuries, but their designation also propelled recognition and improvement of burn rehabilitation in the community.

NIDRR is one of the 3 components of the Office of Special Education and Rehabilitative Services within the U.S. Department of Education and is dedicated to examining the long-term effects of various injuries. For a number of years, NIDRR has supported rehabilitation model systems, first for spinal cord injury (SCI) and, more recently, for traumatic brain injury (TBI). The model system program has led to common data-injury (SCI) and, more recently, for traumatic brain injury (TBI) for epidemiologic studies. They have also produced hundreds of descriptive and treatment studies on rehabilitation for these types of disabilities.

The Burn Model Systems (BMS) of Care were established in 1994. Three burn treatment centers received awards of 36 months in duration to provide leadership in rehabilitation as a key component of exemplary burn care and to advance the research base of rehabilitation services for burn survivors. The 3 funded centers were tasked with establishing and carrying out projects that provide a coordinated system of care including emergency care, acute care management, comprehensive inpatient rehabilitation, and long-term interdisciplinary follow-up services. The BMS centers were also expected to carry out innovative projects for the delivery, demonstration, and evaluation of comprehensive medical, vocational, and other rehabilitation services to meet the wide range of needs of people with burn injuries. In the late 1990s, a fourth center was funded, and the BMS target population was expanded to include children. The 4 centers have developed a longitudinal database that contains information on over 2708 adults and more than 1300 children (BMS Database). Separate funding of the Burn Model Systems Database Coordinating Center (BMS/DCC) was established in 1998. The BMS/DCC may be viewed online at http://bms-dcc.uchsc.edu.

This supplement focuses on some recent findings generated by site-specific and multisite data collection. Each of the 4 centers is represented, as is the DCC. In selecting the studies, we attempted to give readers a sample of the range of rehabilitation issues faced by people who survive large and/or serious burn injuries. Some topics, such as the need for strengthening, are expected areas of focus, whereas others, such as the effects of poor pain control, might be less common in a discussion of rehabilitation.

We begin with an overview of the types of rehabilitation issues faced by patients with severe burn injuries. Much of this summary is based on a review of the burn rehabilitation literature published by Esselman et al.4 What is apparent from this overview is that burn rehabilitation involves certain topics that would be immediately evident to specialists in this area, such as treatment of contractures, heterotopic ossification, neuropathies, and difficulty returning to work. However, there are many complications of burn injuries that are not so apparent, such as sensitivity to temperature extremes, sleep difficulty, pruritus (itching), and the impact of societal reactions to burn-related cosmetic disfigurement. The overview by Esselman5 is followed by an article describing practical issues related to managing a 4-center database. The 4 centers that participate in the BMS submit their data to a database coordinating center. In their discussion, Lezotte et al6 discuss not only how the integrity of such data is insured but also how potential pitfalls and threats to validity are anticipated and managed.

We next turn to the effects of exercise on burn rehabilitation. Severe burn injuries can result in marked skeletal muscle catabolism and weakness, as well as in diminished aerobic capacity. The article by de Lateur et al7 focuses on a 12-week, 36-session treadmill aerobic exercise program, based on preset quotas and work-to-tolerance guidelines. Their randomized, controlled study found improvements in aerobic capacity in the

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No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

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0003-9903/07/8812S-11708$32.00/0

doi:10.1016/j.apmr.2007.10.001

treatment group relative to controls. Suman and Herndon focus on children with particularly large surface-area burn injuries (greater than 40% total body surface area [TBSA]). From their randomized controlled study, the authors concluded that 12-week exercise programs completed either in a rehabilitation center or at home result in improvements in lean body mass and muscle strength relative to no-exercise control. Further, there is evidence that these beneficial effects may persist for at least 3 months after treatment.

A very deep burn in a joint area creates a number of rehabilitation challenges, but little has been published on this topic. Holavanahalli et al began to remedy this deficit in the literature by studying hand function after deep (full-thickness) hand burns in 32 survivors using total active motion, the Jebsen-Taylor Hand Function Test, and the Michigan Hand Questionnaire. Their discussion provides useful information about how functional deficits are manifested with such burn injuries and how preventative and therapeutic rehabilitation can be designed accordingly.

The next 2 studies focus on the effects of burn pain or on efforts to attempt to control it. Edwards et al determined how pain at discharge was associated with risk for suicidal ideation at 6-month and 1-year follow-ups. Pain was a predictor of suicidal ideation, providing more and particularly compelling evidence for the need to control pain effectively after a burn injury. We now know that pain medication frequently falls short of controlling burn pain and that nonpharmacologic interventions are highly desirable. Sharar et al report on 3 ongoing studies that use immersive virtual reality, a novel form of distraction, to reduce pain during burn physical therapy.

Our final area of focus is on long-term outcome after burn injuries. The area of vocational return after burn injuries has received little attention in the literature and yet is one that can represent high costs to a patient and society. Esselman et al identified several of the barriers that prevent timely return to work in 88 patients, using scheduled phone interviews. Baker et al report a rare study on young adults who were burned as children (83 subjects who received burn injuries of at least 30% of TBSA). Their finding that the majority of patients have physical and psychologic outcomes in the normative range (when compared with nonburned age-mates) is another important lesson from a rehabilitation perspective. These results remind us that it is not helpful to people with disability to “overpathologize” or make broad negative assumptions about outcome. It is more important to focus on the unique areas of rehabilitation that some burn survivors will require.

This supplement provides a number of articles on the wide variety of rehabilitation issues that burn survivors must face. Several investigators in this supplement report on randomized controlled studies on topics where such designs have been largely nonexistent until now. Overall, the numbers of patients with injuries and the size of these injuries are greater than those typically seen in the literature. We hope that this series of articles show that the NIDRR-sponsored model systems are advancing the state of the science with burn injuries, as they have long done with TBI and SCI.

References
Burn Rehabilitation: An Overview

Peter C. Esselman, MD


Burn injuries result in significant physical and psychologic complications that require comprehensive rehabilitation treatment and coordination with the acute care burn team. This interdisciplinary rehabilitation treatment is focused on preventing long-term problems with scarring, contractures, and other problems that limit physical function. Adequate pain management and recognition of psychologic issues are important components of treatment after burn injuries. Burn injuries present significant barriers to community integration, but many people can successfully return to work and other activities.

Key Words: Burns; Rehabilitation. © 2007 by the American Congress of Rehabilitation Medicine

Burn injuries cause significant physical and psychologic complications that require an interdisciplinary rehabilitation team working closely with the acute care burn team. In the United States, there are an estimated 500,000 people treated for burn injuries every year, with 40,000 hospitalizations. Although prevention measures such as smoke alarms in homes and changes in workplace safety have resulted in a decreased incidence of burn injuries, deaths caused by burn injury are the fifth most common cause of unintentional injury deaths in the United States.

Overall mortality caused by burn injuries has declined significantly because of the development of comprehensive burn centers with the associated advances in treatment, including improvements in the resuscitation of patients with severe burns, topical antimicrobial agents, newer antibiotics, early excision and grafting, and more recently, the use of artificial skin substitutes. In the 1980s, the median lethal dose (LD$_{50}$) defined by the size of burn resulting in death in 50% of patients, was 65% of the total body surface area (TBSA), and this has improved to a TBSA of over 80%. Because small burns do not have a high risk of mortality, the most significant improvement in survival has been in people with large burns (>50% of TBSA). In a study of children admitted with significant burn injuries caused by large burns (>60% of TBSA), the mortality rate was 33.3% during 1974 to 1980 and only 14.3% during 1991 to 1997. In this study there were no mortalities during 1991 to 1997 in people with burns of less than 60% of TBSA.

An inhalation injury significantly increases the risk of mortality unless the burn is very small (<10% of TBSA). Age is also an important predictor of survival. The LD$_{50}$ TBSA is relatively low in the very young, but it increases with age and decreases again in the elderly. For example, the LD$_{50}$ for those over age 70 years is estimated to be approximately 30% of TBSA. Variables during hospitalization such as sepsis and ventilator dependency are additional predictors of mortality.

The majority of adults with burn injuries are young men, and 60% of all burn injuries are caused by fire. Scald burns are more common in children, accounting for 30% of all burn injuries in children and only 10% in adults. The industrial workplace exposes workers to the risk of burn injuries, including high-voltage electrical injuries, and accounts for a large number of burn injuries. In the National Institute on Disability and Rehabilitation Research (NIDRR)–funded Burn Model System (BMS), although only 59% of adults were employed before their burn injuries, 23% of all the people in the database sustained their injuries in the workplace. In another study of the Model System database of people who were employed before their burn injuries, 42% were burned at the workplace. These studies underscore the need to assist patients’ return to the workplace, often the place where the injury occurred.

The improved survival of people with large burn injuries has increased the need for comprehensive rehabilitation services during hospitalization and transition to the community. Physical complications after burn injuries are caused by contractures, hypertrophic scarring, weakness due to loss of muscle mass, heterotopic ossification, amputations, and nervous system injury. People with burn injuries frequently have difficulty with thermoregulation and pruritis. Adequate assessment and management of pain and psychologic issues are also important after burn injuries.

Physical Complications

A common and clinically significant complication after severe burn injuries is contractures leading to decreased range of joint motion, joint deformities, and deformities of the facial structures. Contractures can be caused by immobility and heterotopic ossification at the elbow joints but are frequently caused by hypertrophic scarring. Hypertrophic scarring is characterized by red, raised, and rigid scar tissue that contracts and limits normal motion of the skin. Studies document a prevalence of hypertrophic scarring ranging from 32% to 67% in people with severe burn injuries. Hypertrophic scarring is often treated with pressure garments to provide continuous pressure to the healing skin. but pressure garments are difficult to put on and are often uncomfortable, resulting in inadequate compliance with their use. Scarring is also treated with splinting, range of motion (ROM) exercises, and stretching. There are few controlled studies that evaluate the effectiveness of pressure garments, splinting, and stretching after burn injuries. Further research is needed to evaluate treatments aimed at preventing hypertrophic scarring and contractures that result in long-term functional impairments and disabilities.

Patients with severe burns have increased catabolism with loss of lean body mass that leads to weakness and decreased functional ability. People with burn injuries will often com-
plain of weakness and fatigue causing difficulty in completing daily activities and returning to work. Studies have documented that treatment with anabolic agents and exercise in people with severe burn injuries results in increased strength and lean body mass.

Full-thickness burns damage the dermal appendages, including the sweat glands, resulting in problems with thermoregulation. The inability to adequately regulate body temperature and sensitivity to heat affects a person’s ability to complete physical activity and return to work in hot environments.

Amputations after burn injuries are complicated by the associated fragile skin and contractures that make prosthetic fitting challenging. Major amputations are common in high-voltage electrical injuries, but thermal injuries can frequently result in finger amputations. Although upper-extremity or lower-extremity amputations will result in significant problems with daily activities, a study of children with burn injuries of more than 80% of TBSA showed that finger amputations are also associated with significantly greater dependence with activities of daily living.

Neuropathy is common after burn injuries, and studies have documented an incidence from 11% to 41%. Neuropathy can involve a single peripheral nerve (mononeuropathy), can involve 1 or more peripheral nerves consistent with mononeuritis multiplex, or can present as a generalized polyneuropathy. Neuropathy after burn injury is often not recognized or diagnosed but can affect strength and function.

Pruritus frequently occurs after severe burn injury, but the exact prevalence is not known. One survey of patients after burn injury reported an overall prevalence of 15% with persistent pruritus and 44% with occasional pruritus. Pruritus can be treated with medication and other modalities but is often a symptom that has a significant impact on quality of life (QOL).

Pain Management

Pain management is an important part of a comprehensive treatment program after burn injuries. Acute burn injuries result in constant background pain, but the need for daily painful treatments such as wound débridement and ROM exercises results in episodic procedural pain. Pain management requires a coordinated plan by the burn team that includes medication management, and it is important to adequately treat background pain with long-acting medications and procedural pain with short-acting pain medications. There is also good evidence that the use of hypnosis and virtual reality can decrease pain and lessen the need for pain medications.

Psychosocial Adjustment

The evaluation and treatment of posttraumatic stress, depression, anxiety, and sleep disturbances are important after burn injuries. Symptoms of posttraumatic stress, such as reexperiencing the trauma and increased arousal, are common early after a burn injury, and at 1 year postinjury approximately 20% of people meet diagnostic criteria for posttraumatic stress syndrome. A number of factors contribute to the development of symptoms of posttraumatic stress, but studies have shown that the size of the burn injury does not predict posttraumatic stress symptoms. Over 50% of people with burn injuries report moderate or severe depression symptoms early in their hospitalizations, and almost half report moderate to severe depression at 2 years postinjury. The severity of the burn injury, as measured by the percentage of TBSA, does not predict psychologic problems after burn injuries. A person’s coping style or the presence of a higher level of psychologic symptoms during early recovery after a burn injury are predictive of longer-term psychologic issues.

Community Integration

Treatment to improve community integration, such as the return to work, school, and community activities, is increasingly important given the increased survival of people with large burn injuries. People with burn injuries have difficulties returning to work and school and with participation in social activities. Most people admitted to burn units are able to return to work, with an average time off work of 17 weeks and up to 90% of people followed up at 2 years postinjury having returned to work. A study of people with burn injuries who were employed at the time of injury showed that they were more likely to sustain a hand burn and have hand surgery, indicating that hand burns are more common in work-related injuries, which affects the ability to return to work.

Burn Rehabilitation Research

A systematic review of the burn rehabilitation literature in 2006 showed a large body of literature supporting rehabilitation treatment after burn injuries but few controlled studies supporting rehabilitation techniques used in the treatment of subjects with burn injuries. Additional research is needed to examine the effectiveness of rehabilitation interventions after burn injury including treatment of hypertrophic scar and treatments to support the transition to the community. Funding for the necessary research can come from a variety of sources including the National Institutes of Health and NIDRR. Since 1994, NIDRR has funded BMS centers under their Disability Rehabilitation Research Projects (DRRP). NIDRR states that “The purpose of the DRRP program is to plan and conduct research, demonstration projects, training, and related activities to develop methods, procedures, and rehabilitation technology that maximize the full inclusion and integration into society, employment, independent living, family support, and economic and social self-sufficiency of individuals with disabilities, especially individuals with the most severe disabilities, and to improve the effectiveness of services...”

The future of the field of burn rehabilitation depends on researchers evaluating current treatments and developing new and innovative treatments to improve the function and QOL of people with burn injuries.

Acknowledgment: Derived in part from content presented in the following:


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ORIGINAL ARTICLE

Assets and Liabilities of the Burn Model System Data Model: A Comparison With the National Burn Registry

Dennis C. Lezotte, PhD, Rebecca A. Hills, MSPH, Sonya L. Heltshe, MS, Radha K. Holavanahalli, PhD, James A. Fauerbach, PhD, Patricia Blakeney, PhD, Matthew B. Klein, MD, Loren H. Engrav, MD


Objectives: To determine whether the Burn Model System (BMS) population represents a larger burn population and to investigate threats to internal and external validity in a multicenter longitudinal database of severe burns.

Design: Cohort data for the BMS project have been collected since 1994. Follow-up data have been collected at 6, 12, and 24 months postburn. Demographic and burn characteristics of the BMS population were compared with those of patients in the National Burn Registry (NBR).

Setting: The BMS, which collected data for these analyses from 5 regional burn centers in the United States, and the NBR dataset, which is a registry of information collected through the Trauma Registry of the American College of Surgeons and includes data from 70 hospitals in the United States and Canada.

Participants: BMS study participants were severely burned patients treated at 1 of the 5 participating burn centers. We compared the BMS population with that of the NBR both in total and filtered to include only patients with comparable injuries.

Interventions: Not applicable.

Main Outcome Measures: Comparable demographic and burn characteristics contained in both the NBR and the 5-center BMS longitudinal database and baseline and follow-up distributions of demographic variables and burn characteristics in the BMS database.

Results: Although minor deviations in demographic distributions were found between the BMS and NBR and between discharge and follow-up populations, our results show that the BMS population sample is internally and externally valid and is adequate for answering research questions.

Conclusions: Cohort studies examining long-term outcomes have the potential flaw of using a nonrepresentative study population. The BMS population was found to be sufficiently representative, but future analyses will require cautious and purposeful application of statistical adjustment strategies.

Key Words: Burns; Cohort studies; Longitudinal studies; Multicenter studies; Rehabilitation.

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RESEARCH ON BURN INJURIES and other disabilities has been limited by the lack of longitudinal data on large samples of patients. Fortunately, the number of large databases is growing. Analyzing data from large samples requires that certain steps are taken to ensure that analyses lead to valid conclusions. An example of a large patient data set that is amenable to such statistical scrutiny is that of the Burn Model Systems (BMS), established by the National Institute on Disability and Rehabilitation Research (NIDRR).

NIDRR began funding the BMS Data Coordination Center (BMS/DCC) in 1994. At that time, the BMS/DCC developed comprehensive guidelines to address the operational processes and timing for collecting and transferring data between each BMS clinical site and the DCC. The DCC processes, corrects, and combines study data; it then publishes the combined database for the BMS investigators on its Web page (http://bms-dcc.uchsc.edu) for sharing and scientific analyses.

NIDRR’s model system programs were originally developed to show the value of a comprehensive integrated continuum of care for people with spinal cord injury (SCI), traumatic brain injury (TBI), or burn injury. The 3 BMS programs include 28 centers (with only 4 burn centers at present) that directly conduct or indirectly sponsor research activities designed to improve interventions that optimize levels of community participation, employment, and quality of life for people with SCI, TBI, and burns.

The utility of NIDRR-funded SCI, TBI, and burn research largely depends on how well practitioners can relate relevant findings to the needs of their particular patients. Practitioners can further benefit from practical information about the scientific utility of data from large samples; if the underlying science behind epidemiologic studies is not sound, they must be informed.

The burn data center’s goal is to ensure high-quality research. This starts with defining and implementing useful and rigorous data models for eventual statistical analyses. Although we seek the highest quality informatics solutions for database design for these projects, the practice of research may constrain the use of ideal database design. That is, clinical research goals and local clinical constraints often determine how studies, especially longitudinal outcomes studies, are conducted and how data are collected and processed. Consequently, outcomes studies that collect cohort data are more common than the more rigorous randomized controlled trial (RCT) study design. Although such loss of rigor is unfortunate, cohort studies are not without merit. With statistical adjustment to account for con-
founding variables and effect-modification, they can provide valuable information.

Frequently in rehabilitation outcomes research, quasi-experimental designs are invoked—often because the criterion standard RCT is not feasible, ethical, or cost effective. Examples of the most widely used quasi-experimental designs used include prospective cohort, retrospective case-control, nested case-control, and pre- and postintervention study designs. Such nonrandom study designs are widely used in population-based epidemiologic and outcomes studies.

The data management strategy adopted by the model systems projects is to produce useful, accurate, and comprehensive data regarding burn care and rehabilitation. Our role in collecting and disseminating data is to identify potential problems, if any, in BMS study methodologies, data representation, and study generalizability so that researchers can appropriately process the information we provide. For a summary of the BMS data management strategies and accomplishments, refer to the recent article by Klein et al, wherein they describe our processes and provide summary statistics of major critical variables.

Most studies contributing data to the BMS use nonrandomized study designs. Consequently, this brings the usefulness of our data into question. Use of our data for scientific publications and for promoting appropriate burn care policies requires our data to be highly scientific and representative. One purpose of this study was to determine whether the BMS population is representative of the larger burn population. To quantify the level of generalizability of the BMS study population, we compared the demographic characteristics of the BMS population with those of the population included in the National Burn Registry (NBR), a well-established national, voluntary registry started by the American Burn Association (ABA).

Levels of variation that exist between distributions of BMS data and the ABA national data repository (the NBR) are described. Also, we describe differences within BMS demographic characteristics that arise because of attrition in serial assessments in our longitudinal research projects.

A secondary goal of this article was to identify potential shortcomings of quasi-experimental designs, in general and specifically in BMS studies, and to suggest compensatory methods of adjusting for possible study design weaknesses. We identify precautions that can be taken in either the data collection or the data analysis phase to produce sound results. We provide comments and general strategies for analyzing these data; most of these are multivariate adjustment techniques for cohort data.

METHODS

Data Sources and Study Populations

The NIDRR BMS study is a long-term prospective longitudinal study of the rehabilitation of severely burned patients. Members of the BMS project included severely burned patients from 5 regional burn centers. The project aims to identify and develop interventions that lead to better short- and long-term outcomes, especially the reintegration of injured people into their communities. Five sites have collected data for the project since it began in 1994. Subjects are followed up for 2 years postburn; after discharge, data are collected at 3 time points: 6 months, 1 year, and 2 years postburn.

Criteria for severe burns include burns that meet any of the following conditions: (1) deep second- and third-degree burns greater than 10% of total body surface area (TBSA) in patients under 10 or over 50 years old; (2) deep second- and third-degree burns greater than 20% of TBSA in other age groups; (3) deep second- and third-degree burns with serious threat of functional or cosmetic impairment that involve the face, hands, feet, genitalia, perineum, or major joints; (4) third-degree burns greater than 5% of TBSA in any age group; (5) deep electrical burns including lightning injury; (6) inhalation injury with burn injury; or (7) circumferential burns of the extremities and chest.

Principal investigators developed the BMS study criteria after consideration of NIDRR’s priorities and limitations of study resources. Burn patients qualify as NIDRR subjects if they (1) meet the clinical criteria for a severe burn injury as defined above; (2) receive treatment in the BMS from the time of burn (outpatient or inpatient) for primary burn wound closure; (3) are of any age (a case is considered pediatric if age is <16y at time of burn and adult if age is ≥16y at time of burn); (4) will be provided some rehabilitation services at the BMS, including psychiatric, physical, occupational, recreational, psychological, vocational, or other traditional rehabilitation therapies throughout the 2 years after the burn injury and agree to follow-up assessments at 6 months postburn, 1 year postburn, and 2 years postburn; (5) understand and sign an institutional informed consent to participate, or if unable, a family or legal guardian understands and signs an informed consent for the patient; and (6) agree to release data collected at discharge and at the subsequent follow-ups to the data center so that all data can be combined and used for research purposes.

People are not in the BMS database if (1) they die in the hospital before being discharged from the initial acute injury admission, (2) they will not or cannot provide follow-up responses, or (3) they do not sign the informed consent or data release forms.

We compared distributions of demographic characteristics in ABA/NBR data with corresponding distributions found in the NIDRR BMS database. The NBR database contains records on burn patients collected from 70 burn centers in the United States and Canada. For the purposes of our analysis, data from acute burn admissions (ie, NBR classifications of admission defined as acute admission, burn injury related; self/EMS [emergency medical services] admit; hospital referral; emergency room referral; or burn center referral) to the burn facility occurring between 1994 and 2004 were selected for evaluation. Year of admission was used for this criterion in lieu of year of burn because it was a more reliable variable in the NBR dataset. Records were excluded from analysis if age or year of burn fields were missing or invalid. To compare with our longitudinal rehabilitation study wherein subjects must be alive at discharge, patients in the NBR who died in the hospital were excluded from the comparison dataset, giving a final comparable dataset, namely, “NBR/all.”

Adult and pediatric (age at burn <16y) cases are analyzed separately, primarily because BMS inclusion dates of adults (1994–present) and children (1998–present) differ. The BMS project did not include pediatric cases until the second funding cycle (October 1997), at which time 1 regional site was replaced with a new international pediatric burn program. The concern is that this new clinical site is a dedicated pediatric burn center that contributes small numbers of adults and many children with very large burns. Moreover, a large proportion of these complicated cases come from outside the United States.

The BMS study criteria (described earlier) for inclusion in the BMS study population were applied to the NBR/all sample to derive a second comparison dataset, namely, “NBR/criteria”; this reduced the adult population from 73,407 to 14,790 and the pediatric population from 24,736 to 3616 (fig 1). Because the application of the BMS selection criteria to the NBR was based on available data elements in the NBR dataset, minor losses of sensitivity and specificity in the classification algorithm exist.
That is, applying our criteria to the NBR sample was inexact because of the limited variables in the NBR dataset and slightly different definitions of common concepts in the BMS and NBR data values. For example, a criterion required identification of deep, second-degree burns, but only full-thickness and partial-thickness estimates are included in the NBR. Consequently, it was not possible to determine deep second-degree burns; we therefore used only full-thickness surface area in our criteria. Also, it was impossible to identify in the NBR data either burns that posed a threat of functional or cosmetic impairment in the face, hands, feet, genitalia, perineum, or major joints or circumferential burns. We therefore included any patient with a full-thickness burn on the head, neck, face, hands, feet, or genitalia.

### Data Analysis

Frequency distributions for demographic and burn-related characteristics were calculated for the NBR/all sample, the smaller NBR/criteria sample, and the BMS sample. Chi-square goodness-of-fit tests were used to compare the various distri-
butions of the BMS variables with the smaller NBR sample only. Comparisons with the larger NBR populations are not formally reported here because these results are identical, in all cases, to those found in the analyses performed for the smaller NBR/criteria population. Goodness-of-fit method was used because of an overlap of subjects in the 2 (BMS, NBR) populations, because most members of the BMS project contribute data annually to the NBR as well. NBR distributions are used as the true or reference values. In this case, the BMS distributions are compared (using 1-sample test vs 2-sample test) with the assumed fixed and known distributions determined in the NBR database. The large sample size of the current BMS database (N=3800) renders most statistical comparisons with the NBR population distributions statistically significant. The major concern to researchers using BMS data, however, is how well these data represent the general burn population nationally. Consequently, our analyses and discussions focus on the magnitude of differences among the various distributions rather than statistical significance.

In addition, we compared the discharge demographic characteristics of BMS patients with the demographic characteristics of those who returned for the 6-month assessment, which is a subset of our total study population. Similarly, we performed the same comparison for those with 12-month assessments and those with 24-month assessments. In these comparisons, the BMS/discharge population was used as the reference population. Typical chi-square tests of association were inappropriate because of nonindependent samples: samples at 6, 12, and 24 months were subsamples of the discharge population. We therefore made these comparisons using goodness-of-fit methods. These analyses were performed separately for the adult and pediatric populations.

SAS was used for all statistical analyses. RESULTS

Threats to External Validity

Clinicians and researchers should always question the external validity of any published study, where external validity refers to the investigator’s ability to generalize results beyond the studied sample. The BMS project is often criticized because of the seemingly restrictive criteria applied to its BMS patients. To assess threats to external validity we compared our data with the NBR dataset. Table 1 identifies distributional differences between NBR/criteria and BMS subjects. Separate frequency distributions for the BMS, NBR/all, and NBR/criteria groups for many of their common variables are provided. The statistical comparisons contained in this table relate to the BMS and NBR/criteria populations wherein all BMS entry criteria have been applied to the NBR population.

In Table 1, statistical significance of all tests performed is most notable. This is not surprising because of the large sample sizes of the 3 (NBR/all, NBR/criteria, BMS) populations. Consequently, the absolute differences, or clinical significance, become more relevant in consideration of internal and external validity. Selection bias (table 2) is the biggest threat to external validity. Other pitfalls (eg, synergism, confounding, effect-moderation) usually associated with cohort studies can be controlled or adjusted for during the analysis phase. If there are similar distributions and all values of the variable exist in the data, the use of multivariate statistical adjustments will compensate for distributional differences found in the sample populations. Appropriate adjustments can identify real risk and causal factors that apply to the target populations of interest. (Criteria for determining whether a risk factor is causal are provided in appendix 1.)

Table 1 provides insight into possible selection bias in the BMS population. The adult BMS study population is slightly younger and has larger burns, often caused by fire or flame. Compared with the NBR/all distributions, the BMS population has more burns involving inhalation injury, with a larger proportion using ventilators for long periods. When compared with the NBR/criteria group, the opposite is true. This NBR/criteria group includes more than twice the proportion of inhalation injuries as the BMS group, with a higher percentage on ventilators for more than 7 days. Consequently, the adult BMS study population has longer hospital stays than both NBR populations (85% with 8–183d vs 40% and 72% in the NBR/all and NBR/criteria groups, respectively).

The BMS pediatric study population is older (72% >3 years old vs 49% and 60% in the NBR/all and NBR/criteria groups, respectively). Again, the BMS group consists of more severe burns, predominately due to fire or flame. The BMS and NBR/criteria groups have similar length of stay patterns (33% and 28% for 1–7d, the lowest category, respectively). However, in the NBR/all group, approximately 74% of patients have hospital stays of 1 to 7 days. The fact that the BMS pediatric population has more severe burns with possibly more complicated acute care needs is not surprising given the make-up of the BMS clinical sites. Of the 4 sites now contributing to the BMS database, one is dedicated to treating very serious, complicated burns in the pediatric population at little or no cost to the patient’s family. The remaining 3 general burn centers contribute pediatric cases, but the majority of pediatric cases come from the dedicated pediatric BMS site.

Threats to Internal Validity

Threats to internal validity in longitudinal studies emerge from 2 equally unfavorable conditions associated with protocol design and data collection. First, internal validity is compromised if the research protocol, data definitions, or analytic strategies are inappropriately applied during the study and/or are not consistent with the predefined research objectives. Moreover, in longitudinal studies, an additional threat to internal validity emerges when samples at subsequent assessment periods are inconsistent or substantially different from the initial targeted sample at baseline. To assess threats to internal validity in our longitudinal evaluations, we made cross-sectional comparisons of characteristics among the baseline (discharge) distributions in the BMS dataset to subsets of compli-ant subjects at each of the 3 follow-up periods and to BMS subjects who complied completely by undergoing all 4 assessments (discharge, 6, 12, and 24mo). From table 3 we can observe that BMS follow-up data are not systematically missing. They are therefore as generalizable as they would be if a random sample had been used at each time point. Again, despite statistically significant differences in distributions for a few characteristics, in general, these differences are not large and should have little effect on statistical inference. The fact that all statistical tests comparing body surface area burned at discharge among the various subpopulations were nonsignificant provides positive evidence that missing observations are not due to severity of burn complications.

Although we can make generalizations based on table 3, reevaluation of the various sources of missing observations for each analytic assessment we performed is a necessary precaution for researchers. That is, certain scientific questions that use a specific assessment instrument may result in slightly different patterns of missing responses than would others. If patterns are suggestive of nonrandom missing data, even usually correct and appropriate analyses can lead to faulty inferences and inappropriate generalizations.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Adults (≥16y)</th>
<th>Children (&lt;16y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NBR/All</td>
<td>NBR/Criteria</td>
</tr>
<tr>
<td>Total</td>
<td>73,407</td>
<td>14,790</td>
</tr>
<tr>
<td>Age group (y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–2</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>3–5</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>6–10</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>11–15</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>16–20</td>
<td>7309 (9.96)</td>
<td>1209 (8.17)</td>
</tr>
<tr>
<td>21–30</td>
<td>15,439 (21.03)</td>
<td>2844 (19.23)</td>
</tr>
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<td>31–40</td>
<td>15,968 (21.75)</td>
<td>3380 (22.85)</td>
</tr>
<tr>
<td>41–50</td>
<td>14,190 (19.33)</td>
<td>3034 (20.51)</td>
</tr>
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<td>8655 (11.79)</td>
<td>1942 (13.13)</td>
</tr>
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<td>61–70</td>
<td>4968 (6.77)</td>
<td>1127 (7.62)</td>
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<td>71–80</td>
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<td>813 (5.50)</td>
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<td>441 (2.98)</td>
</tr>
<tr>
<td>Length of stay</td>
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<td></td>
</tr>
<tr>
<td>0–7d</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>8–30d</td>
<td>44,280 (60.32)</td>
<td>4197 (28.38)</td>
</tr>
<tr>
<td>31–183d</td>
<td>23,587 (32.13)</td>
<td>7280 (49.22)</td>
</tr>
<tr>
<td>6mo to 1y</td>
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</tr>
<tr>
<td>1y+</td>
<td>60 (0.07)</td>
<td>20 (0.07)</td>
</tr>
<tr>
<td>Days on ventilator (d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–7d</td>
<td>ND</td>
<td>ND</td>
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<tr>
<td>8–30d</td>
<td>55,121 (92.97)</td>
<td>5951 (80.23)</td>
</tr>
<tr>
<td>31+</td>
<td>1168 (1.97)</td>
<td>843 (7.05)</td>
</tr>
</tbody>
</table>

NOTE. Values are n (%).
Abbreviations: NA, not applicable; ND, no data.
*Chi-square goodness-of-fit test between frequency distribution of the NBR/criteria population and the NIDRR database population.
DISCUSSION

Generalizability

The perceived inability to generalize results to the larger burn population is not a real threat for the BMS project. Because BMS sites contribute to both the NBR and BMS databases, our BMS population will always be a subset of the larger burn population. In addition, from the analyses provided here, the BMS population, in fact, is not very different from the general burn population and these minor differences should not preclude generalizing to the larger group. In fact, the larger differences in processes of care among all major burn centers, the various distinctions in the target populations around the United States, and the variations in rehabilitation strategies used at the various burn centers far outweigh the slight differences that we have
### Table 3: Demographic and Burn Characteristics of the NIDRR Sample at Discharge and the 6-, 12-, and 24-Month Follow-Ups and of the Group With Records for All 3 Follow-Up Intervals

<table>
<thead>
<tr>
<th>Variable</th>
<th>Discharge</th>
<th>6 Months</th>
<th>1 Year</th>
<th>2 Years</th>
<th>All</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group (y)</td>
<td>N=3255</td>
<td>N=2054</td>
<td>N=1741</td>
<td>N=1347</td>
<td>N=1093</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>0–2</td>
<td>301 (9.25)</td>
<td>133 (6.48)</td>
<td>117 (6.72)</td>
<td>109 (8.09)</td>
<td>67 (6.13)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3–5</td>
<td>276 (8.68)</td>
<td>127 (6.18)</td>
<td>109 (6.26)</td>
<td>89 (6.61)</td>
<td>56 (5.12)</td>
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</tr>
<tr>
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<td>242 (7.43)</td>
<td>129 (6.28)</td>
<td>113 (6.49)</td>
<td>81 (6.01)</td>
<td>45 (4.12)</td>
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</tr>
<tr>
<td>11–15</td>
<td>248 (7.62)</td>
<td>143 (6.96)</td>
<td>115 (6.61)</td>
<td>76 (5.64)</td>
<td>47 (4.30)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>16–20</td>
<td>273 (8.39)</td>
<td>176 (8.57)</td>
<td>146 (8.39)</td>
<td>109 (8.09)</td>
<td>88 (8.05)</td>
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</tr>
<tr>
<td>21–30</td>
<td>421 (12.93)</td>
<td>276 (13.44)</td>
<td>229 (13.15)</td>
<td>164 (12.18)</td>
<td>147 (13.45)</td>
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</tr>
<tr>
<td>31–40</td>
<td>551 (16.93)</td>
<td>373 (18.16)</td>
<td>311 (17.86)</td>
<td>235 (17.45)</td>
<td>210 (19.21)</td>
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</tr>
<tr>
<td>41–50</td>
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<td>310 (15.09)</td>
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<td>183 (16.74)</td>
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</tr>
<tr>
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<td>208 (10.13)</td>
<td>177 (10.17)</td>
<td>135 (10.02)</td>
<td>126 (11.53)</td>
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<tr>
<td>61–70</td>
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<tr>
<td>71–80</td>
<td>80 (2.46)</td>
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<td>Ethnicity</td>
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<td>N=2031</td>
<td>N=1702</td>
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<td>White</td>
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</tr>
<tr>
<td>Black</td>
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<td>242 (11.92)</td>
<td>200 (11.63)</td>
<td>133 (10.03)</td>
<td>94 (8.67)</td>
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</tr>
<tr>
<td>Hispanic</td>
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<td>394 (19.40)</td>
<td>334 (19.42)</td>
<td>244 (18.40)</td>
<td>140 (12.97)</td>
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</tr>
<tr>
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<td>45 (2.22)</td>
<td>41 (2.38)</td>
<td>36 (2.71)</td>
<td>34 (3.15)</td>
<td>&lt;.001</td>
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<td>39 (1.92)</td>
<td>36 (2.09)</td>
<td>27 (2.04)</td>
<td>25 (2.32)</td>
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</tr>
<tr>
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<td>21 (1.03)</td>
<td>18 (1.05)</td>
<td>14 (1.06)</td>
<td>13 (1.20)</td>
<td>&lt;.001</td>
</tr>
<tr>
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<td>N=2023</td>
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<td>993 (49.09)</td>
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<td>N=1548</td>
<td>N=1195</td>
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<tr>
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<td>406 (22.26)</td>
<td>356 (23.00)</td>
<td>280 (23.43)</td>
<td>253 (24.83)</td>
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</tr>
<tr>
<td>Hispanic</td>
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<td>164 (12.54)</td>
<td>123 (11.76)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Asian</td>
<td>52 (1.82)</td>
<td>45 (2.22)</td>
<td>41 (2.38)</td>
<td>36 (2.71)</td>
<td>34 (3.15)</td>
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<tr>
<td>Native American</td>
<td>46 (1.43)</td>
<td>39 (1.92)</td>
<td>36 (2.09)</td>
<td>27 (2.04)</td>
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</tr>
<tr>
<td>Other</td>
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</tr>
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<td>.134</td>
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<td>.766</td>
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<td>406 (22.26)</td>
<td>356 (23.00)</td>
<td>280 (23.43)</td>
<td>253 (24.83)</td>
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</tr>
<tr>
<td>No</td>
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<td>1418 (77.74)</td>
<td>1192 (77.00)</td>
<td>915 (76.57)</td>
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</tr>
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<td>N=2036</td>
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<td>N=1720</td>
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<td>285 (14.00)</td>
<td>215 (12.50)</td>
<td>148 (11.15)</td>
<td>117 (10.82)</td>
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<td>8–30d</td>
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<td>31–183d</td>
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</tr>
<tr>
<td>6mo to 1y</td>
<td>15 (0.47)</td>
<td>7 (0.34)</td>
<td>9 (0.52)</td>
<td>9 (0.68)</td>
<td>5 (0.46)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>1y+</td>
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<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

NOTE. Values are n (%).

*Chi-square goodness-of-fit test between frequency distribution at discharge (left column) and each follow-up interval as well as the sample with data at all 3 data collection intervals.

showed between our study’s population and the larger burn population.

Stratified analysis is a very simple and direct analytic strategy for handling situations in which generalizations may be a concern. Although stratified analysis can lead to many and varied conclusions, especially when the numbers of strata are large, this analytic method allows consumers to separately adopt some conclusions and reject others that are deemed to be less generalizable and/or reliable. For example, one should always consider stratified analyses between adult and pediatric burns when assessing outcome data among these 2 populations. This recommendation is not new; most burn literature presents
stratified analyses and findings because of the unique etiology, natural course, and rehabilitation strategies for pediatric cases that set them apart from the adult burn population. Analyses that combine these groups can have confounding bias that obscures any reasonable interpretations. In addition, in the presence of major confounding (ie, effect modification), the recommended analytic strategy is to conduct stratified analyses.

Compensatory Analytic Methods

In longitudinal studies, significant resources are consumed trying to ensure subject compliance. Ensuring that subjects remain on their designated interventions and that they return for their required assessments, or both, is costly in follow-up studies. The BMS project has been struggling to improve follow-up assessment rates, especially in some subgroups. Nevertheless, the 2 main concerns in longitudinal analyses presented by BMS researchers are nonrandom missing data and large attrition rates. Random losses of subjects’ information at random time points specified in the BMS follow-up protocols are of less concern than subject attrition. At present, we have more and powerful analytic methods that compensate for losses in the precision of estimates generated from random missing data than methods we have for handling problems accruing from shrinking sample sizes due to attrition. Statistical packages like SAS, SPSS, GLIM, R and S-Plus now offer more powerful multivariate modeling and analysis procedures that provide efficient and effective data analyses. These procedures allow analysts to easily declare random effects and to prespecify complex covariance structures that account for unbalanced (missing data) study designs. For example, unstructured, compound-symmetric and auto-regressive correlation structure assumptions allow us to estimate critical variance structures implied in the data from series of observations with missing data at various time points. Repeated-measures analyses that use SAS’S Proc Mixed or GLIMIX are much more efficient, accurate, and precise than the traditional split-plot analysis of variance (ANOVA) or multivariate ANOVA methods previously used. Because of the availability of these sophisticated analytic procedures to adjust for random missing data, analyses in the presence of missing information is now a manageable analytic problem. Concerns about nonrandom missing data, however, still remain a major issue. Statisticians are providing guidance, analytic tests, and adjustment procedures when studies are at risk for this limitation.

Unfortunately, variations exist in data processing strategies both within and between the different BMS centers. Although each clinical site manages its own data collection processes, they are required to submit commonly collected data elements to our centralized data center. Between model systems, variation in data collection strategies, especially with respect to patient tracking for follow-up assessments, can have a significant influence on the study’s validity. Censored or missing data generated by subject “lost to follow-up” can sometimes produce very different follow-up rates across model systems, systematically dissimilar study groups across the combined study population, and sometimes a group very different from the original target population of interest, thus affecting our study’s internal and external validity. Missing data at designated follow-up times do not affect the makeup of the study population across time. The loss of subjects, however, will compromise internal validity and lead to incorrect inferences or models if there are selective losses during the evaluation period. For example, less severe burns do not require constant or long-term medical attention but do require vigilant psychosocial counseling. In these cases, the more severe cases are more likely to return to the medical facility for follow-up and consequently affect the make-up of the studied population. Because these undesirable influences are not completely avoidable, we always use analytic methods (like those mentioned above) that best compensate for these problems and allow for accurate inferences.

Epidemiologists and outcomes researchers are often interested in factors that are not only associated with outcomes but are factors that cause particular diseases or outcomes. Causation or causal factors in epidemiologic and outcomes studies typically refer to risk factors, exhibiting the property that the expected outcome (disease burden) vanishes (diminishes) as the punitive factors are removed (reduced). Showing causation in observational studies is difficult and requires the researcher to discover necessary and sufficient associations between the factors and outcome, biologic plausibility for the association, and no alternative explanations. (See appendix 1 for the proposed set of conditions that imply causation in quasi-experimental studies, because causation cannot be determined directly in observational studies.)

Appendix 1 outlines a strategy for establishing causality in cohort studies. Although the criteria are clear, the process of applying these criteria is rarely straightforward. None of the criteria are either necessary or sufficient for making a causal inference. In fact, strict adherence to any 1 criterion without consideration of bias, random error, synergism, confounding, and effect modification could result in incorrect assignment of causality. These common statistical concepts (eg, bias, random error, synergism, confounding, effect modification) are well defined in numerous textbooks on biostatistics and epidemiology. The general recommendation, however, is to always test for, and if present, adjust for the effect of these conditions.

Other sources of misinterpretation, excluding bias, are easily overcome by appropriate multivariate statistical modeling strategies, which often amount to no more than simple statistical adjustments. Well-known analytic methodologies for incorporating complex statistical adjustments during the analysis phase of an investigation include logistic or Poisson regression for discrete or count data and mixed models, generalized linear models, and nonlinear multiple regression modeling for continuous outcomes measures. The remaining liability of using cohort study designs, once appropriate statistical adjustments are made, is related to the degree in which sources of bias (see table 2) are accounted for during the phases of study design and data collection.

Issues of Generalizability of BMS Subjects

Because observational studies are an important tool in outcomes research, the analysis, interpretation, and generalization of results to broader populations must proceed with analytic diligence. The potential lack of generalizability in the BMS project is related to selection and response biases. Selection bias is cumulative and results from several procedural steps that researchers must apply during the recruitment and follow-up assessment periods. Sources of selection bias emerge in our BMS project for one or more of the following reasons: (1) all BMS subjects represent those types of patients who would normally be admitted to a regional burn center (this is probably not a serious limitation); (2) application of our entry criteria identifies study subjects who meet criteria for serious burns and consequently selects a more severely injured study population; (3) because of the longitudinal nature of our study and regard for improvement of rehabilitation outcomes, very serious cases that result in a hospital death are not included; (4) because of consent issues, our study selects only certain types of personalities—subjects who consent to participate in a longitudinal
study and provide medical data to multiple centers and researchers; and finally, (5) our study is more likely to select subjects who will remain compliant with the designated research protocol and return to the BMS for follow-up assessments.

Most analyses of BMS data, in general, avoid comparing sample characteristics of BMS subjects directly with those of other populations. We generally focus on differences due to alternative rehabilitation regimes within and across the different model systems. BMS researchers are mostly concerned with how many and how quickly people return to an acceptable state of community reintegration and with barriers to early and effective reintegration. For assessing changes and improvement rates, we necessarily use internal controls that naturally occur by varying burn severity levels, levels of disability, or burden of burn injury—for example, in the BMS study population. These results are generalizable after appropriate adjustments so that other non-BMS burn centers can apply our estimates of relative improvement or degradation to their specific reference populations and make reasonable estimates, inferences, and associations for their own patient populations. Researchers should be cautious about blindly computing simple descriptive population estimates from our BMS data despite the reasonable similarity between the BMS and the NBR datasets described in this article. Whenever criteria are applied to study populations, simple incidence and prevalence measures can become distorted, thus providing an inaccurate representation of more general population characteristics.

CONCLUSIONS

We identify the inherent liabilities of the BMS multicenter data collection project that produced a longitudinal, observational outcomes database. Although most of the common liabilities of quasi-experimental studies are present in this information resource, the BMS project has produced important information with notable assets. First, data are produced from multiple large burn centers with a wide range of burns, burn care, and burn rehabilitation programs. Second, the diversity of the BMS population is derived from the very different characteristics of the subjects obtained from center to center. Third, the participating burn centers represent a wide range of burn injuries with a broad spectrum of burn care and rehabilitation programs used to achieve optimal outcomes. Finally, because of the diversity of injury severity and subsequent rehabilitation needs seen in these burn centers, our participating centers have experienced research staff who are well trained and experienced in conducting complicated research protocols. Consequently, this database is distinguished from other outcomes databases by being operational for over 12 years and having the largest collection of sequential outcomes measures on burn victims currently available for monitoring trends in physical, psychologic, and social reintegration. Numerous scientific publications (see http://bms-dcc.uchsc.edu) and presentations have been generated from these data and from related, site-specific substudies of this long-term funded project.

By appropriately controlling selection bias and controlling for variation in distributions of study subjects (eg, age, race, TBSA burned) using adjustments and appropriate analyses to control for confounding and effect-modification, we can improve external validity. However, it is not possible to improve internal validity prospectively with complex analysis strategies. Internal validity is affected by other sources of bias, and generally these biases come from inaccurate data. Avoiding the many sources of bias requires diligence in precise conceptualization, detailed operational definitions, and instituting well-described processes to accrue data that are internally valid. Although the BMS project team believes that considerable effort has been spent on acquiring quality data, subjects’ lack of compliance in the follow-up protocol remains the biggest threat to internal validity and is difficult to control with limited resources.

Although there is no strict policy against sharing BMS data, the rationale for not providing BMS data openly is a concern for misrepresentation of results because of the internal and external validity threats described in this study. Assurance that appropriate analytic methods will be used and important validation steps are taken must accompany the use of these data. Internally, our policy for producing scientific publications and presentations that use BMS data is to share final drafts with investigators at the other clinical centers for critical review and comments to ensure accuracy and generality. Our goal is to ensure that results and inferences, based on the BMS database, are appropriate and that they generalize to the larger population of burn victims.

APPENDIX 1: EPIDEMIOLOGIC CRITERIA FOR CAUSE AND EFFECT RELATIONSHIPS

Causation and Disease

Associations are easily found in observational studies when many risk factors are evaluated. Finding associations is not the problem—understanding and interpreting them is. What types of association are possible? Statisticians and epidemiologists are concerned about 4 types of discovered associations. These are summarized as follows:

- **Spurious associations:** caused by chance alone.
- **Artifactual associations:** for example, misclassification or interviewer bias.
- **Indirect associations:** confounding—for example, the association between 2 factors may actually be due to a third factor.
- **Causal associations:** most difficult to determine.

Consequently, over the years a number of researches have derived postulates for causality. There have been numerous attempts to unify the concept of causal factors under the many different study designs and for many different scientific questions relying on the scientific method of proof. Criteria have been proposed that, if met, increase the probability that a risk factor is causal.

Most of the proposed criteria were derived from the original Henle and Koch postulates or are traced back to the works of John Stuart Mill (1865) and which are referred to as Mill’s cannons. The original postulates were proposed many years ago to address necessary and sufficient conditions for a causal relationship between parasites and diseases. This original set is summarized as follows:

1. The parasite occurs in every case of the disease in question and under circumstances that can account for the pathologic changes and clinical course of the disease.
2. It occurs in no other disease as a fortuitous and nonpathogenic parasite.
3. After being fully isolated from the body and repeatedly grown in pure culture, it can induce the disease anew.
APPENDIX 1: EPIDEMIOLOGIC CRITERIA FOR CAUSE AND EFFECT RELATIONSHIPS (cont’d)

A unifying set of conditions has been proposed by Alfred Evans24 in a review article that summarizes many different sets of postulates that address defining causal relationships in various levels of scientific investigations. His set of unifying concepts is summarized in the table below. Although the criteria listed here may help us determine whether an exposure or characteristic is a causal risk factor for a disease, their application to a given hypothesis is never an uncomplicated or straightforward affair. None of the criteria are either necessary or sufficient for making a causal interpretation. In fact, strict adherence to any one of them without other considerations could result in incorrect conclusions.4,15

Why is it still so difficult to establish causality? Many reasons exist but some include

1. Multifactorial etiology
2. Multiplicity of effects
3. These criteria depend on change (what about genes?) or how high is high if the cause is a continuous variable (high blood pressure?)
4. Imperfect knowledge
5. Need to show no alternative explanations for the increased incidence in the outcome in the subpopulation with the risk factor.

Criteria for Showing That a Risk Factor is a Causal Factor

1. Prevalence of the disease should be significantly higher in those exposed to the putative cause than in those not so exposed.
2. Exposure to the putative cause should be present more commonly in those with the disease than in controls without the disease when all risk factors are held constant.
3. Incidence of the disease should be significantly higher in those exposed to the putative cause than in those not so exposed as shown in prospective studies.
4. Temporality: the disease should follow exposure to the putative agent with a distribution of incubation periods on a bell-shaped curve.
5. A spectrum of host responses should follow exposure to the putative agent along a logical biologic gradient from mild to severe.
6. A measurable host response after exposure to the putative cause should regularly appear in those lacking this before exposure (ie, antibody, cancer cells) or should increase in magnitude if present before exposure; this pattern should not occur in people so exposed.
7. Experimental reproduction of the disease should occur in higher incidence in animals or humans appropriately exposed to the putative cause than in those not so exposed; this exposure may be deliberate in volunteers experimentally induced in the laboratory or demonstrated in a controlled regulation of natural exposure.
8. Elimination or modification of the putative cause or of the vector carrying it should decrease the incidence of the disease (control of polluted water or smoke or removal of the specific agent).
9. Prevention or modification of the host’s response on exposure to the putative cause should decrease or eliminate the disease (immunization, drug to lower cholesterol, specific lymphocyte transfer factor in cancer).
10. The whole thing should make biologic and epidemiologic sense.

- The putative cause may exist in the external environment or in a defect in host response.
- Summary of Alfred Evans, World Health Organization Serum Reference Bank, Department of Epidemiology and Public Health, Yale University School of Medicine, Received December 22, 1975.

Below are some additional and overlapping concepts that are used to talk about causal associations in observational studies. The degree to which scientific investigations address the postulates just listed or the concepts discussed next and provide explanations of critical rationale, the stronger the arguments for causal relationships in the absence of higher levels of scientific investigations.

Important concepts for assessing causal associations:

1. Strength of the association. The stronger the observed association, the less likely it is that the association is entirely due to various sources of error that might distort the results. Thus, in general, weaker associations do not lend as much support to a causal interpretation.
2. Dose-response effect. The observation that frequency of disease increases with the dose or level of exposure usually lends support to a causal interpretation. In the absence of such an effect, the investigator may not be able to rule out certain alternative explanations, such as a threshold effect or a saturation effect. An observed dose-response effect may be due entirely to a graduated distortion of bias.
3. Lack of temporal ambiguity. It is very important for the researcher to establish that the hypothesized cause preceded the occurrence of the disease. In general, this task is more difficult when investigating diseases with long latent periods and study factors that change over time.

The above criteria can be applied to the findings of a single study, and thus, they may be regarded as internal validity issues. However, any of them may be satisfied in some studies and not in others that deal with the same hypothesis. The following criteria are not necessarily study-specific and depend, to a certain extent, on a priori knowledge.

4. Consistency of the findings. If all studies dealing with a given relationship produce similar results, a causal interpretation is enhanced.
5. Biologic plausibility of the hypothesis. If the hypothesized effect makes sense in the context of current biologic knowledge, we are more likely to accept a causal interpretation. However, biologic plausibility cannot be demanded of a hypothesis, because the current state of knowledge may be inadequate to explain our observations.
APPENDIX 1: EPIDEMIOLOGIC CRITERIA FOR CAUSE AND EFFECT RELATIONSHIPS (cont'd)

6. **Coherence of the evidence.** If the findings do not seriously conflict with our understanding of the natural history of the disease or with other accepted facts about disease occurrence (eg, secular trends), a causal interpretation is strengthened. In essence, this criterion combines aspects of consistency and biologic plausibility and, therefore, is similarly delineated as described in points 4 and 5.

7. **Specificity of the association.** If the study factor is found to be associated with only 1 disease or if the disease is found to be associated with only 1 factor (after testing many possible associations), a causal interpretation is suggested. However, this criterion cannot be used to reject a causal hypothesis, because many factors have multiple effects and all (or most) diseases have multiple causes.

References


Supplier

a. Version 9.1; SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.
Augmented Exercise in the Treatment of Deconditioning From Major Burn Injury

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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<.01; t=-3.17, P<.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<.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.

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, Celi14 and Suman15 and colleagues have examined the effects of exercise in children with thermal injury. Celi 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 al16 further emphasized the need for rehabilitation efforts to combat catabolism and concluded that...
sepsis and excessive hypermetabolism are associated with muscle catabolism.

Fordyce et al.\textsuperscript{16-21} 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.\textsuperscript{16} Ehde et al.\textsuperscript{16} 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, split 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).\textsuperscript{22} 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\textsuperscript{\textregistered} (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 (V\textsubscript{O\textsubscript{2}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 (V\textsubscript{O\textsubscript{2}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 protocol\textsuperscript{24} at each assessment. The BRUCE protocol is accepted by ACSM\textsuperscript{25} as standard procedure for ambulatory stress testing and is based on the seminal work of cardiologist Robert Bruce in the early 1970s.\textsuperscript{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...
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’ VO₂max. Respiratory gas analysis was performed and oxygen uptake (VO₂), carbon dioxide production (VCO₂), and respiratory quotient were measured using the SensorMedics Vmax 229 metabolic system. VO₂max 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 VCO₂ as a function of VO₂. This plot created 2 lines intersecting where metabolic acidosis occurs, determining the VO₂max.

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 ± standard deviation (SD) between the subjects’ burn injury and the

<table>
<thead>
<tr>
<th>ALLOCATION</th>
<th>FOLLOW-UP</th>
<th>ANALYSIS</th>
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<td></td>
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<td>Work to Quota and Usual Care Intervention (n=20)</td>
<td>Received allocated intervention (n=20)</td>
<td>Did not receive allocated intervention (n=0)</td>
<td>Lost to follow-up (n=6) - chose to withdraw from participation due to intensive time commitment</td>
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<td>Usual Care Alone</td>
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<tr>
<td>Intervention (n=19)</td>
<td>Received allocated intervention (n=19)</td>
<td>Did not receive allocated intervention (n=0)</td>
<td>Lost to follow-up (n=8) - chose to withdraw from participation due to intensive time commitment</td>
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Fig 1. Augmented exercise program randomized control trial CONSORT flowchart.
start of their participation in the study was 37.5 ± 23.3 (range, 9–122). There were no significant differences in sex (Pearson $\chi^2$ test = 1.79, $P = .41$), age ($t = 1.26$, $P = .21$), employment status (Pearson $\chi^2$ test = 3.40, $P = .33$), type of burn injury (Pearson $\chi^2$ 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 $\chi^2$ 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 $\chi^2$ 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 $V_\text{O}_2$ ($F = .68$, $P = .51$). 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 $V_\text{O}_2$ ($F = .07$, $P = .93$).

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 measured by $V_\text{O}_2$ max. 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 $V_\text{O}_2$ max, in comparison with the SFR group ($F = 4.16$, $P = .05$). 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 therapy 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 $V_\text{O}_2$ max. 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, 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-being resulting from the release of endorphins secreted during muscular activity, as well as through other mechanisms.

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**Table 1: Group Demographic Characteristics**

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

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**Table 2: Baseline Group Stress Test Statistics**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Weight ± SD (kg)</th>
<th>Mean Resting Heart Rate ± SD (bpm)</th>
<th>Mean Maximum Heart Rate ± SD (bpm)</th>
<th>Mean $V_\text{O}_2$ max ± SD</th>
<th>Absolute $V_\text{O}_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All groups</td>
<td>35</td>
<td>82.2 ± 20.4</td>
<td>85.3 ± 15.6</td>
<td>163.2 ± 22.1</td>
<td>21.7 ± 7.0</td>
<td>1809.0 ± 687.5*</td>
</tr>
<tr>
<td>SFR</td>
<td>11</td>
<td>88.0 ± 20.9</td>
<td>84.6 ± 15.8</td>
<td>167.6 ± 20.9</td>
<td>23.2 ± 8.6</td>
<td>1993.7 ± 865.3</td>
</tr>
<tr>
<td>WTT + SFR</td>
<td>11</td>
<td>82.9 ± 17.2</td>
<td>88.5 ± 15.5</td>
<td>152.5 ± 24.3</td>
<td>21.2 ± 5.8</td>
<td>1787.4 ± 611.8</td>
</tr>
<tr>
<td>WTQ + SFR</td>
<td>13</td>
<td>76.6 ± 22.5</td>
<td>83.1 ± 16.3</td>
<td>168.5 ± 19.5</td>
<td>20.8 ± 6.7</td>
<td>1659.5 ± 581.2†</td>
</tr>
</tbody>
</table>

*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 cardiopulmonary 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 expected 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 a 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

### Table 3: Group Stress Test Statistics Post-Test

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Weight ± SD (kg)</th>
<th>Mean Resting Heart Rate ± SD (bpm)</th>
<th>Mean Maximum Heart Rate ± SD (bpm)</th>
<th>Mean V̇O₂max ± SD (L/min)</th>
<th>Absolute V̇O₂ (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All groups</td>
<td>35</td>
<td>85.8±23.6</td>
<td>79.8±14.7</td>
<td>168.4±17.6</td>
<td>25.7±6.1</td>
<td>2215.3±647.7*</td>
</tr>
<tr>
<td>SFR</td>
<td>11</td>
<td>89.6±30.3</td>
<td>77.5±9.6</td>
<td>171.2±18.6</td>
<td>24.7±7.3</td>
<td>2215.1±750.6</td>
</tr>
<tr>
<td>WTT + SFR</td>
<td>11</td>
<td>86.1±17.9</td>
<td>80.9±15.1</td>
<td>165.2±17.9</td>
<td>26.5±4.3</td>
<td>2269.3±533.6</td>
</tr>
<tr>
<td>WTQ + SFR</td>
<td>13</td>
<td>82.5±22.9</td>
<td>80.9±18.3</td>
<td>168.9±17.3</td>
<td>25.8±6.6</td>
<td>2166.0±694.3†</td>
</tr>
</tbody>
</table>

*Based on 34 participants.
†Based on 12 participants.
treatment group compared with children who received a placebo. 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.

References

Objective: To determine whether the benefits of exercise by burned children are maintained 3 months after the exercise program is concluded.

Design: Randomized, controlled prospective study.

Setting: Pediatric burn hospital.

Participants: Twenty severely burned children with a 40% or greater total body area burn, with main outcome measures completed before exercise training, immediately after 12 weeks of exercise training (intervention), and 12 weeks after training ended.

Intervention: Randomization into a 12-week standard rehabilitation program at home (n=9) or a 12-week standard hospital rehabilitation program supplemented with an exercise-training program beginning 6 months after burn injury (n=11).

Main Outcome Measures: Assessment of lean body mass (LBM) using dual-energy x-ray absorptiometry and of leg isokinetic muscle strength at a speed of 150°/s were done before, after the 12-week rehabilitation and exercise training program, and 3 months after the exercise program was completed (12mo postburn). The effects of exercise on the dependent variables were analyzed by repeated-measures analysis of variance. If we found a significant overall effect of time and/or intervention, we did a post hoc test for multiple comparison (Holm-Sidak). Results are expressed as mean ± standard error.

Results: The mean percentage increase in LBM and muscle strength was significantly greater in the exercise group (6.4%±1.9%, 40.7%±8.6%, respectively) than in the no-exercise group (1.9%±2.6% vs 3.4%±4.5%, respectively). Three months after cessation of the exercise program, LBM remained relatively unchanged in the no-exercise group (3.5%±1.8%). In contrast, LBM in the exercise group increased significantly (10.7%±6.4%, P=0.03). In addition, muscle strength further increased by 17.9%±10.1% in the exercise group versus 7.2%±3.4% in the no-exercise group, although neither percentage increase was significant (P=0.08 for exercise vs P=0.61 for no exercise). Absolute values in LBM and muscle strength for both groups at 12 months postburn continued to be below historical or concurrent age-matched, nonburned children.

Conclusions: Participation in an exercise program resulted in a greater improvement in LBM and muscle strength in the exercise group than in the no-exercise group. Three months after the exercise training ended, there were persistent mild-to-moderate increases in LBM and muscle strength. Absolute levels continued to be below previously reported nonburned, age-matched values, however, which underscores the need for continued exercise to improve LBM and muscle strength in severely burned children.

Key Words: Burns; Child; Exercise; Muscles; Rehabilitation.

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SEVERE BURNS RESULT in persistent and extensive skeletal muscle catabolism and weakness,1 which is worsened by prolonged physical inactivity.2,3 The current standard of care consists of rehabilitation exercises of occupational therapy (OT) and physical therapy (PT), which can be done in a hospital setting or in a patient’s home. There are problems with compliance because these exercises are typically done without expert supervision, and often lack structure. Muscle catabolism and weakness persist, however, despite therapy. The physical frailty associated with severe burns is often confounded by cardiac and systemic shock, hypermetabolism, respiratory injury, sepsis, postburn seizures, compromised bone formation, major surgeries, malnourishment, disturbed growth patterns, and psychosocial issues.1,4-7 Additionally, low physical work capacity and muscle strength are major obstacles to a burn victim’s return to school and performance of activities of daily living (ADLs).

We have previously reported8,9 that a 12-week supervised and structured program of resistive exercise implemented 6 months post-burn in severely burned children increases muscle strength and muscle mass. Because ADLs are integrated functions that require muscle strength and endurance, an effective resistance exercise program may contribute to the rehabilitation of severely burned children by increasing their muscular strength and their capacity to do work.10-12 Although exercise training improves physical function in severely burned children, it is not known whether these functional and structural benefits last for at least 3 months after a 12-week exercise program. Previous studies in nonburned adults have found that strength performance in general is maintained for up to 4 weeks of inactivity.13,14 In nonburned children, however, an 8-week strength-training program followed by 8 weeks of detraining resulted in a weekly mean strength loss of 3%. Furthermore, and most important, values in the strength of these trained children regressed toward the values of the untrained control group within 8 weeks of inactivity.15

Therefore, we designed a study in which we assessed lean mass and muscle strength before and after a 12-week supervised and structured exercise program in a group of severely burned children. In addition, we assessed whether any resulting
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benefits would be maintained, to a greater extent than in subjects in a no-exercise group, 3 months after the exercise program ended.

METHODS

Burned Subjects

We randomized severely burned children, ages 7 to 18 years, into either a no-exercise group or an exercise group. We only enrolled patients with 40% or more total body surface area (TBSA) burned, as assessed by the “rule of nines” method, during excision surgery in the acute phase of injury. Patients were excluded if they had 1 or more of the following: leg amputation, anoxic brain injury, psychologic disorders, quadriplegia, or severe behavior or cognitive disorders. The parent or legal guardian gave informed consent during the first day of admission to acute care. Eleven patients were assigned to participate in a 12-week, in-hospital physical rehabilitation program supplemented with an individualized and supervised exercise-training program. The no-exercise group was to receive standard of care. That is, a home-based written set of instructions of PT and OT exercises. All patients received similar standard medical treatment from the time of hospital admission until time of discharge. In addition, both groups were discharged with similar standard medical and rehabilitation care until the 6-month postburn timing point.

At 6 months postinjury, all patients returned to Shriners Hospitals for Children in Galveston, TX, for exercise testing. After completing the tests, the exercise group began participation in a 12-week in-hospital physical rehabilitation program supplemented with an individualized and supervised exercise-training program. In contrast, the no-exercise group returned home, if they had no surgical needs, to continue the prescribed OT and PT standard regimen, which has been described previously. Patients in the no-exercise group did not receive an exercise prescription from an exercise physiologist at any time during the study period from 6 months postinjury to 9 months postinjury. The institutional review board at our institution approved the study. Our comparison group was comprised of age-matched, healthy, nonburned children.

Exercise Testing

Exercise assessments were made for all subjects at 6 months and 9 months postinjury. These time points were equivalent to assessments made before and immediately after training in the exercise group. There was no formal training for the no-exercise group, therefore tests were done at 6 and 9 months after injury. Finally, all burned children underwent exercise testing 3 months after cessation of the specific intervention (ie, 1y postinjury).

Prior to strength testing, patients were made familiar with the exercise equipment and were instructed on proper weightlifting techniques. They sat quietly for approximately 15 minutes before we recorded their resting measurements, after which we measured their vertical height and body weight.

Strength Measurements

Strength testing was conducted on day 1, before the start of the exercise program, and after 6 weeks of training; we used a Biodex System 3 dynamometer. The isokinetic test was performed at an angular velocity of 150°/s on the dominant leg extensors. We chose this speed (vs lower or higher angular speeds) because it was well tolerated by the children of all ages in both groups. The 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. All patients were made familiar with the Biodex test in the same manner. First, the test administrator demonstrated the procedure for the patients, then it was explained to them, after which they practiced the actual movement, without load, by doing 3 submaximal repetitions. More repetitions were not permitted so as to prevent fatigue. The anatomic axis of the knee joint was aligned with the mechanical axis of the dynamometer before the test. After the warm-up repetitions, subjects performed 10 maximal voluntary muscle contractions (full extension and flexion) consecutively without resting between contractions. The test was repeated after 3 minutes of rest to minimize the effects of fatigue.

Peak torque values were calculated with the Biodex software system and we selected the highest value of the 2 trials. Peak torque was corrected for gravitational moments of the lower leg and the lever arm. We used a similar procedure to assess the muscle strength in children without burn injuries. Peak torque values were again calculated with the Biodex software system and the highest value of the 2 trials was selected. Peak torque was corrected for gravitational moments of the lower leg and the lever arm.

3 Repetition Maximum Test

Only the patients in the exercise group were tested, after a 30-minute rest, to determine the amount of weight or load to use as baseline loads in the first week of the 12-week program. Subjects were tested in the following order of exercises: bench press, leg press, shoulder press, leg extension, biceps curl, leg curl, and triceps curl. The 3 repetition maximum (3-RM) load was determined as follows. After being instructed in the correct weightlifting technique, patients warmed up with lever arm and bar (or wooden dowel) and became familiar with the movement. They then attempted to lift a weight 4 times (ie, 4 repetitions). If the fourth repetition was achieved successfully and with correct technique, subjects were permitted 1-minute rest. After resting, they were instructed to lift a progressively increased amount of weight or load at least 4 times. If they lifted a weight that allowed successful completion of 3 repetitions of the task, but were unable to perform a 4th repetition because of fatigue or an inability to maintain the 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-mo, 9-mo, end of detraining), lean body mass (LBM) measurements were taken for both groups by dual-energy x-ray absorptiometry (DXA), using the QDR 4500A software. Scans were taken with the patient laying supine on the scanning table. We followed the previously described protocol for obtaining a whole body scan. Briefly, DXA with pediatric software can measure the attenuation of 2 x-ray beams, of which 1 is high energy and the other 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.

Exercise Training Program

All subjects were sedentary before starting the exercise program and had never participated in an exercise-training program. Training sessions consisted of resistance and aerobic exercises.

Resistive training. We used 8 basic resistive exercises: bench press, leg press, shoulder press, leg extension, biceps...
curl, leg curl, triceps curl, and toe raises. At no time did the exercise group use the Biodex dynamometer. All exercises were done using variable resistance machines or free-weights, and were done 3 days a week (Monday, Wednesday, Friday). During the first week, the patients became familiar with the exercise equipment and were instructed in proper weightlifting techniques. The weight or load lifted was set at 50% to 60% of their individual 3-RM. During the second week, the lifting load was increased to a range of 70% to 75% (4-10 repetitions) of their individual 3-RM and was maintained for weeks 2 through 6. After this, training intensity was increased to a range of 80% to 85% (8-12 repetitions) of the 3-RM for weeks 7 through 12.

**Aerobic training.** Each training session also included aerobic conditioning exercises on a treadmill or cycle ergometer and was also done 3 days a week. Each session lasted 20 to 40 minutes and participants exercised at 70% to 85% of their previously determined individual peak oxygen consumption ($V_{O2\text{peak}}$). All sessions were preceded by a 5-minute warm-up period on the treadmill at an intensity of less than 50% of each individual $V_{O2\text{peak}}$. Heart rate and oxygen saturation were monitored with a pulse oximeter. Rated perceived exertion was obtained at a regular interval. 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 (ACSM) and the American Academy of Pediatrics (AAP). No strength training activities were permitted outside the supervised training session; however, both groups were allowed to pursue their normal daily activities. Patients in the exercise program were required to have participated in at least 33 of the 36 total workout sessions to be considered to be in compliance with the program.

**Home Exercise Prescription**

On completion of the exercise program, or at 9 months postburn, all subjects were given written instructions (home exercise prescription), which described the activities that patients in the exercise group had been performing and which made recommendations for continued participation in aerobic conditioning and strength training. The prescription given the no-exercise group did not describe past activities, but did include recommendations for physical activities. Exercise prescriptions for both groups were similar for both aerobic and strength training. The patient and his/her caregivers were given written instructions on the weight-lifting techniques, on techniques for assessing heart rate and rated perceived exertion, and also on the frequency and duration of exercise. Patients and families were questioned on compliance with program, but the detraining component was of an intent-to-treat design. Details of the home exercise prescription-training program are shown in appendix 1.

**Aerobic Home Exercise Prescription**

We recommended that the prescribed aerobic conditioning exercises be performed 3 to 5 days a week for 20 to 40 minutes a session, with 5-minute warm up and cool down periods included. Suggested activities included using the treadmill, bicycle, rowing machine, cycle ergometer, and elliptical machine; swimming; participating in organized sports; and/or walking and jogging, depending on equipment availability and patients’ interests. Patients and families were instructed on how to assess exercise intensity by using a rated perceived exertion scale throughout each exercise session. An exercise specialist provided all exercise prescriptions, which were in line with guidelines developed by the ACSM and AAP.

**Resistive Home Exercise Prescription**

We recommended that the prescribed resistive conditioning exercises be performed 2 to 3 days a week with a rest day between each session. All patients were instructed to begin with 2 sets of 6 to 10 repetitions and progress to 3 sets of 8 to 12 repetitions over the 12-week period. Eight basic strength training exercises were included: bench or chest press, shoulder press, biceps curl, triceps extension, leg press, leg extension, hamstring curl, and toe raises. All exercises were to be performed, depending on availability, using variable resistance machines, free weights, or body weight. Before leaving the hospital exercise center, all patients and their families were instructed on proper form and weight-lifting techniques. A 3-RM was determined for each exercise and a beginning workload was set at 50% to 60% of this value. Patients were instructed to increase the workload when the final 2 repetitions of each set were no longer difficult. In addition to the gym-based exercise, patients were given a set of diagrams describing a series of exercises that should be performed at home with resistance bands and were instructed in the use of the bands and the performance of the specific exercises. Light, medium, and heavy resistance bands were given and patients were instructed to follow the same guidelines and progression as those performing gym-based activities.

**Children Without Burn Injury**

We recruited 26 age-matched, nonburned, apparently healthy children to compare their LBM and muscle strength with that of the children with burns. Similar data have also been previously reported. Assessments of LBM and muscle strength was similar to that for the burned children but were only done at 1 time point.

**Data Analysis**

All data are expressed as mean ± standard error of the mean (SEM). We analyzed the effects of exercise on the dependent variables by repeated-measures analysis of variance. If there was a significant overall effect of time and/or intervention, we did a post hoc test (Holm-Sidak) for multiple comparisons. Significance was determined and the $P$ value adjusted by the Holm-Sidak method, which accounts for the number of comparisons done. We corrected for differences in LBM by dividing peak torque by LBM.

**RESULTS**

We enrolled 20 burned children (17 boys, 3 girls) in the study and assessed their 1-year complete longitudinal data. Eleven exercise patients and 9 no-exercise patients were tested at 6 and 9 months postburn, and at 3 months after the supervised and structured exercise program ended. The age range for both groups was 7 to 18 years ($13.4 ± 1.8$ years for the no-exercise group vs $11.8 ± 1.5$ years for the exercise group, $P = .30$). There were no differences at 6 months postburn between the groups in age, percentage of TBSA, vertical height, standing weight, and body surface area. At 9 months postburn, both groups had similar levels of absolute vertical height and standing weight, although the change in weight from 6 to 9 months postburn was significant only in the exercise group (difference in means: $0.3kg$ for the no-exercise group vs $2.8kg$ for the exercise group). At 12 months postburn, body weight and vertical height did not differ significantly between groups ($P = .80, P = .78$, respectively) (table 1).

Measurement of total LBM, obtained by DXA, revealed a mean increase of $6.4% ± 1.9%$ (baseline value, $36.90 ± 5.51$kg; $P = .005$)
in the exercise group after 12 weeks of training (fig 1). In contrast, the mean total LBM from 6 to 9 months in the no-exercise group remained relatively unchanged (1.9%±2.6%; baseline value, 34.57±4.10kg; \( P = .565 \)). Three months after cessation of the exercise program, LBM remained relatively unchanged in the no-exercise group (3.5%±1.8%). In contrast, LBM in the exercise group increased significantly (10.7%±4.8%, \( P = .03 \)). Group mean values of LBM are presented in table 2.

There was a significant increase in strength (reflected by peak torque) after 12 weeks of the exercise intervention in the exercise group (40.7%±8.6%; baseline value, 51.30±6.30Nm), but not in the no-exercise group (3.4%±4.5%; baseline value, 47.05±9.21Nm). Three months after cessation of the exercise program, peak torque was further increased in the exercise group (17.9%±10.1%) versus in the no-exercise group (7.2%±13.4%; fig 2), although neither percentage increase was significant (\( P = .08 \) for exercise vs \( P = .61 \) for no exercise).

Similarly, absolute values in peak torque for both groups at 12 months postburn did not differ significantly (\( P = .55 \)). Group mean values obtained for peak torque are reported in table 2.

**DISCUSSION**

Our results indicate that there was an increase in muscle strength and LBM in the exercise group after 12 weeks of exercise, whereas in the no-exercise group, both muscle strength and LBM remain relatively unchanged. Three months after the cessation of supervised and structured training, LBM increased significantly only in the exercise group. In contrast, further increases in muscle strength in both groups were not significant. When expressed in absolute values, between-group comparisons of muscle strength and LBM at any time point did not differ significantly.

To our knowledge, there have been no previous reports of the effects of detraining or cessation of training in burned children after they have participated in a resistance exercise-training program. Our results in this study are in agreement with reported strength gains in nonburned children who trained using various resistance exercise protocols. Reported improvements in strength have ranged from 13% to 74%.\(^{2,27}\) These increases differ from our mean increase of 40%, and may be the result of differences between the studies in the length of the program, frequency of training, and mode of testing (isokinetic vs isotonic). Our results are also in agreement with results of a previous study by our group in which there was a significant increase of 44% in muscle strength after a similar resistance training program.\(^{8} \) Whereas the benefit of exercise training on muscle strength and LBM in burned children has been once more substantiated, our detraining results are in partial disagreement with those reported in the literature concerning nonburned pediatric patients. The few published studies we found reported decreases in muscle strength due to detraining.\(^{15,28} \)

Sewall and Micheli\(^{28} \) reported increases in leg muscle strength of 30% in response to a 9-week progressive resistive strength training program in pre-pubescent children. In contrast, leg muscle strength decreased only 1.3% after 9 weeks of detraining.\(^{28} \) Unfortunately, muscle strength was not assessed in the control group after training, and it is possible that a similar drop could have occurred in that group. In addition, while strength during shoulder flexion increased 96% in the exercise group versus 18% in the no-exercise group, 9 weeks of detraining resulted in an increase in strength of 66%. Again, a lack of details prevent our knowing if the increase was calculated using the start of the 9-week exercise program or the end of the program as the preassessment and the end of the detraining period as the postassessment. In the other study of children, Faigenbaum et al\(^{15} \) reported an increase in leg muscle strength of 54% in response to an 8-week exercise program, but a decrease of 28% in lower-body strength in children after an 8-week detraining period. Our results support the notion that there is not a significant increase in muscle strength after training. Because there is not a decrease, however, the net effect is a relative stability of strength values compared with the end of exercise training.

Again, to our knowledge, LBM and the effects of detraining have not been explored in nonburned or in burned children. Sewall and Micheli\(^{28} \) reported a mean decrease in body weight of .51% during the exercise training period in the exercise group and a gain

---

**Table 1: Demographic Characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Exercise (n=11)</th>
<th>No Exercise (n=9)</th>
<th>Nonburned (n=26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex distribution (M/F)</td>
<td>9/2</td>
<td>NC</td>
<td>17/18</td>
</tr>
<tr>
<td>Age (y)</td>
<td>11.8±1.5</td>
<td>NA</td>
<td>13.5±0.63</td>
</tr>
<tr>
<td>% burn size (TBSA)</td>
<td>61±2</td>
<td>NC</td>
<td>NA</td>
</tr>
<tr>
<td>% burn size (third degree)</td>
<td>52±1</td>
<td>NC</td>
<td>NA</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>149.6±2.5</td>
<td>151.2±2.5</td>
<td>158.2±3.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>51.3±0.6</td>
<td>54.5±0.5*</td>
<td>54.8% P=.03</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SEM. No significant differences were noted in age, % TBSA, height, or weight at 6 months postburn between the exercise and no-exercise groups.

Abbreviations: F, female; M, male; NA, not applicable; NC, no change.

*Significant mean percentage change before and after training (\( P < .05 \)).
of 6.7% in the control group. There was, however, a gain of 3.48% over the subsequent 9 weeks of detraining in the group that previously exercised. The control group’s body weight was not assessed during the detraining period. The assumption in the Sewall and Micheli study was that body weight would reflect fat mass, which may not be appropriate. Our study shows that exercise significantly increases lean mass. After 12 weeks of detraining, however, lean mass continued to significantly increase in the exercise group, but not in the no-exercise group. This is important for 2 reasons. One, exercise does increase LBM to a higher level than if there is no exercise, which is a desirable effect in burned children. Two, despite cessation of the exercise stimulus, LBM did not decrease in either group.

We are pleased with the effects of exercise on LBM and, to some extent, muscle strength in burned children. We expected that once our “formal” supervised training stopped, both structure (ie, LBM) and function (ie, muscle strength) would deteriorate. This was not the case, as mean values in structure and function did not decrease. In fact, the increase of 18% in muscle strength may be of physiologic significance despite a lack of statistical significance ($P = .09$). It is important to note, however, that although values in burned children had a tendency to increase after the formal training period, the absolute values in muscle strength and LBM were still below values for nonburned children (see table 1).

Direct or indirect effects of our “formal” exercise training may be operant during the detraining period and may help explain the lack of a decrease in muscle strength or a continued increase in LBM. These include increased spontaneous physical activity,29 improved nutritional habits,30 improved behavior modification strategies,31,32 and also a time effect on burn-induced catabolism.18 In addition, there is the possibility that complete cessation of physical activities (or detraining) did not occur, as some children may have continued to be physically active. We did not formally evaluate physical activity patterns or behavior from the 9- to the 12-month postinjury time point. When briefly questioned as to their physical activities during this time period, all the children acknowledged no formal, structured, supervised, intensity-controlled (ie, percentage of peak aerobic capacity set or heart rate monitored) exercise activities, and no-resistive training activities. Some children in both groups, however, did report increased play and child-like activities. Nevertheless, again it is important to note that in burned children, the absolute values in muscle strength and LBM were still below values for historical or concurrent nonburned children.

Exercise program ended, LBM continued to improve, while there was a pattern of continuing increases in muscle strength ($P = .09$) in the exercise group, but not in the no-exercise group. Based on these findings, we advocate that an exercise program be initiated to improve muscle strength and LBM. We recommend a continued exercise maintenance program, however, either to minimize loss of exercise-induced benefits, or to facilitate further gains in those benefits. This is particularly important when we compare the values of muscle strength and LBM in burned versus nonburned children.

### Study Limitations

We recognize that the possibility of a type II error in this study cannot be ruled out and that the number of subjects in both groups is small.

### CONCLUSIONS

We report here the benefits of a supervised and structured exercise program relative to a home exercise prescription. In addition, there is a continued improvement in these benefits 3 months after the structured and supervised exercise program is stopped. Further studies are needed to determine what type of exercise maintenance program is optimal in maintaining or further improving LBM and muscle strength in burned children. Such studies should also assess how to best improve nutritional habits and spontaneous physical activity, or modify behavior to decrease time spent in sedentary activities.

---

**Table 2: Leg Muscle Peak Torque and Total LBM Results**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Exercise Group</th>
<th>No-Exercise Group</th>
<th>Nonburn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 Months</td>
<td>9 Months</td>
<td>12 Months</td>
</tr>
<tr>
<td>Total LBM (kg)</td>
<td>36.90±5.51</td>
<td>39.12±6.00*</td>
<td>43.33±6.11†</td>
</tr>
<tr>
<td>Peak torque (Nm)</td>
<td>31.30±6.30</td>
<td>40.84±8.24*</td>
<td>46.45±8.56†</td>
</tr>
</tbody>
</table>

*T: Significant difference in percentage change after 12 weeks of stoppage of training program ($P = .05$).
†: Significant difference between burned and nonburned children ($P = .11$).

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![Mean Change in Peak Torque](image.png)

**Fig 2.** Mean percentage change in knee extensor peak torque at 150°/s after 12 weeks of exercise intervention and 12 weeks after cessation of the exercise program. NOTE. Values are mean ± SEM. Absolute peak torque measured in newton-meters was used in the calculation of percentage changes. *$P < .05$ for 6 to 9 months percentage change.
APPENDIX 1: HOME EXERCISE PRESCRIPTION

Resistance Protocol
- Children should perform multiple sets (3 sets) of resistive exercises.
- Resistive exercises should be performed 3 days a week with a day of rest in between.
- Eight basic resistive exercise activities should be used: bench press, squats, shoulder press, leg press, biceps curl, leg curl, triceps curl, and toe raises.
- Children should train 3 sets of overall upper- and lower-body resistance exercises with a 2-minute rest between sets.
- All resistive exercises should be done using variable resistance machines, free-weights or resistance bands (whichever one is readily available). Children can pursue their normal daily activities.

Aerobic Protocol
- Performed 3 to 5 days a week; with each session lasting 20 to 40 minutes.
- Activities can include walking, running, cycling, rowing, and playing sports or games.
- All exercise sessions should be preceded by a 5-minute active warm-up period at a light intensity.

References


Suppliers

b. Hologics Inc, 35 Crosby Dr, Bedford, MA 01730.
c. Ohmeda Medical, 8880 Gorman Rd, Laurel, MD 20723.
Outcomes After Deep Full-Thickness Hand Burns

Radha K. Holavanahalli, PhD, Phala A. Helm, MD, April R. Gorman, MS, Karen J. Kowalske, MD


Objective: To measure hand-specific functional performance after deep full-thickness dorsal hand burns.

Design: Descriptive, cross-sectional study.

Setting: The 2005 Phoenix Society’s World Burn Congress, Baltimore, MD.

Participants: Volunteer sample of burn survivors (N=32) with full-thickness dorsal hand burns with extensor mechanism involvement, who consented to participate.

Interventions: Not applicable.

Main Outcome Measures: Total active motion of joints, Jepsen-Taylor Hand Function Test (JTHFT), and Michigan Hand Questionnaire (MHQ).

Results: Subjects had large burns (mean percentage total body surface area, 58%). Digit involvement was severe, with more than 50% having amputations and 22% with a boutonnière deformity. Forty percent of subjects had poor functional range with total active motion of less than 180°. Scores on the JTHFT were lower than normative scores, and subjects reported most difficulty in performing MHQ activities of daily living (ADLs).

Conclusions: Even with partial amputation or loss of extensor mechanisms, the intact flexor muscles facilitate function by allowing for a modified grasp and enable patients to be independent in most ADL tasks. Training programs can be developed to meet specific goals despite residual hand deformities caused by deep full-thickness burns.

Key Words: Burns; Hand; Hand deformities; Rehabilitation; Treatment outcome.

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INCREASED SURVIVAL, decreased length of hospitalization, and better overall outcomes are all the results of recent advances in burn care management. One area that has largely escaped any sort of empirical attention is the dorsal area of the hand. The many studies looking at outcome after partial-thickness burns to the hands have shown universally good outcomes, using any one of a number of different types of treatment programs. Studies of full-thickness burns again show mostly good outcomes. Severe fourth-degree burn injuries involving tendons, joint capsules, or bone are considered uncommon and make up only 5% of hand burns.1 The functional outcome when the extensor mechanism is damaged is described as universally poor but has not been thoroughly evaluated. Moreover, there is lack of a well-defined method to evaluate functional results.

The method of total active motion described by the American Society for Surgery of the Hand (ASSH) is useful in evaluating burned hands.2 One study3 analyzing hand function in relation to early versus delayed surgical treatment in adults with deep partial-thickness hand burns found that at 3 and 6 months postinjury, the pinch and grip strengths were greater in the group that was treated early. Hand function deficits (deficiency of function of every joint, finger, hand, and arm, in degrees) were also significantly lower in this group compared with the delayed treatment group.3 However, van Zuijlen et al4 assessed long-term (at least 12mo postburn) functional outcome of full-thickness hand burns and found no relationship between postburn day of operation and long-term hand function, which is in contrast to the prevailing consensus that functional outcome is improved by early excision and grafting. In most studies, goniometry reflects the functional outcome of single joints and does not measure the integral function of the hand.5

The burn rehabilitation literature lacks a consistent treatment approach for deep dorsal hand burns, and such injuries tend to do poorly regardless of the treatment used.6 Salisbury6 listed at least 12 potential postburn deformities of a burned upper extremity (apparently independent of how well early care is provided), including (1) first web space adduction contracture, (2) web space contractures, (3) dorsal skin contractures, (4) flexion deformity, (5) metacarpophalangeal joint extension deformities, (6) extensor tendon adhesions, (7) boutonnière deformity, (8) proximal interphalangeal (PIP) flexion deformities, (9) median and ulnar nerve compression syndrome, (10) amputation secondary to ischemic gangrene, (11) elbow and axillary contractures, and (12) heterotopic ossification of the elbow or wrist. However, despite such significant hand impairment, functional independence and resumption of preburn lifestyle remain important goals in burn care rehabilitation.

More recently, outcomes questionnaires to measure disability or functional limitations have been favored over physiologic measures alone that quantify specific impairment.7 The frequent observations by therapists that increasing patients’ passive range of motion (ROM) or minimizing scarring does not always result in an improvement in functional performance8 is a reason for the important shift in focusing on the quantification of functional limitations that are caused by impairment(s). Hand function has also been shown as a strong predictor of physical quality of life (QOL) after a massive burn injury.9

Sheridan et al4 found that differences in outcome were associated with the severity of injury after dividing a sample of children with burn injuries into 3 injury and 3 performance-oriented functional categories. They found that among fourth-degree injuries that involved underlying tendon, joint capsule, and usually bone, only 9% of hands had normal or near-normal postinjury function. Eighty-one percent of hands had abnormal function but were able to perform activities of daily living.
(ADLs) with the help of assistive devices. Another 9% could not perform ADLs even with the assistance of such devices. A study examining the relationship among the recovery grip strength, functional outcomes, and work performance found a significant relationship between recovery grip strength and 2 Michigan Hand Questionnaire (MHQ) subscores—the overall hand function and ADLs. A moderate positive correlation approaching significance was found between grip strength and overall MHQ scores. The authors in this study concluded that a recovery grip strength measure should be used along with functional measures to appropriately assess overall hand function after hand trauma. Another study found that 68% of patients reported hand function deterioration, mainly with the nondominant hand. ADLs (76%) and work (59%) were most affected. Patient satisfaction correlated with work performance, aesthetics, and ADLs.

Cartotto focused on the management and late outcomes (5y postinjury) of deep partial- and full-thickness burns and found that key pinch strength, grip strength, and overall mean digital total active motion were all within normal or accepted functional ranges. The MHQ scores were moderate to good across all domains with the exception of aesthetics; pain scores were low, indicating little residual pain.

The objectives of the current study were to measure hand-specific functional performance after deep full-thickness dorsal hand burns and to compare subjective reports and objective assessments of hand function. Most studies have described impairments seen after full-thickness and deep partial-thickness hand burns, but impairments seen after deep full-thickness hand burns have not been thoroughly evaluated. This study aimed to describe the deformities resulting from deep full-thickness burns to the hand and also to compare these impairments with performance on the Jebsen-Taylor Hand Function Test (JTHFT) and scores on the MHQ. Burn survivors, health care providers, and funding sources need to have a better understanding of this very significant functional impairment and its consequences to design and pay for appropriate treatment and facilitate adaptation when appropriate.

METHODS

Setting

Data for this cross-sectional study were obtained from burn survivors attending the 2005 Phoenix Society’s World Burn Congress (WBC) held in Baltimore, MD. At the request of the study investigators, the organizers of the WBC included a flier describing the study and inclusion criteria in the registration packet given to the registered attendees (burn survivors) at the WBC. Inclusion criteria were listed as full-thickness dorsal hand burns with extensor mechanism involvement. The investigators set up a study booth at the WBC, where interested participants voluntarily presented themselves to the study investigators to determine eligibility. Eligibility to participate was determined by 1 of 2 physical medicine and rehabilitation physicians (study investigators) after a detailed examination of the burned hand(s). Eligible participants were then requested to sign an informed written consent form (approved by the institutional review board) to participate in the study.

Participants

The self-selected volunteer sample included 32 burn injury survivors who consented to participate in the study. The sample was predominantly white (78%), with a mean age of 46 years, and included 15 men and 17 women. Data collected for this study included self-reported data and data documented by the physicians after an interview and a physical examination of the burned hand(s). Subject demographics included self-reported data such as age, sex, ethnicity, hand dominance, and employment status. Injury and treatment characteristics were self-reported and included percent total body surface area (TBSA) burn, tendon exposure and/or rupture, amputations, splinting, casting, and pinning of digits. Participants were examined by the physicians for joint fusion to confirm pinning of digits.

OUTCOMES MEASURES

Outcomes measures included measurement of hand impairment and function. Hand impairment was measured using grip and pinch strengths and total active ROM (total active motion) of the digits. Grip and pinch strengths were measured using the standard Jamar dynamometer and a pinch gauge, respectively, using standardized procedures regarding arm positioning. The total active motion for each digit was computed using the method recommended by the ASSH. To calculate the total active motion for each joint, a sum of all the flexion measurements at the MCP,PIP, and distal interphalangeal (DIP) joints was calculated (for the thumb, measurements of the MCP and interphalangeal joints were used), and any extension loss at each of the joints was subtracted from the total flexion.

INSTRUMENTS

Hand function was measured by the JTHFT and the MHQ. The JTHFT is an objective and standardized test of hand function designed to evaluate functional capabilities with 7 test items representative of various hand activities. The test items include (1) writing a short sentence, (2) turning over 3×5-in cards, (3) picking up small objects and placing them in a container, (4) stacking checkers, (5) simulated eating, (6) moving empty large cans, and (7) moving heavy large cans. The time taken to complete each test item is recorded in seconds. The MHQ is a standardized tool that has been shown to be both reliable and valid across diagnostic populations. It is a hand-specific outcomes instrument that measures the health outcome of patients with chronic hand conditions.

The MHQ contains 6 scales: (1) overall hand function, (2) ADLs, (3) pain, (4) work performance, (5) aesthetics, and (6) patient satisfaction with hand function. The SAS scoring code made available by the developers of the MHQ was used to convert the raw score for each of the 6 scales to a score ranging from 0 to 100 (higher scores indicate better performance). The response categories for some questions were reversed and recoded as indicated by the scoring program.

DATA ANALYSIS

Observations were summarized using descriptive statistics. Measures of location, such as mean, standard deviation (SD), median, minimum, and maximum were calculated for continuous data. Frequency distributions were generated for the categorical variables. Spearman rank-correlation coefficients were used to determine the degree of a linear relationship between MHQ subjective reports of hand function and JTHFT objective measures of hand function. SAS software was used for all analyses.

RESULTS

Forty-seven percent of the study sample reported working full-time at the time of study participation. Sixty percent of the sample reported being right-handed, 28% being left-handed, and 12% being ambidextrous. The mean TBSA was 58%, and the mean time from injury was 16 years. The reported average length of time spent in intensive care was 81 days and in acute
NOTE. Values are mean degrees ± SD.

care was 143 days. Eighty-two percent reported having received therapy (inpatient and outpatient therapy) during the stay in the hospital, and 86% rated their compliance with therapy as “excellent” or “good.”

Thirty-nine percent had 1 or more digit amputation(s) of the dominant hand, 46% of the nondominant hand, and 31% had 1 or more digit amputations of both hands. Of the 88 amputations recorded, 19 (22%) were at the MCP joint, 44 (50%) were at the PIP joint, and 25 (28%) were at the DIP joint. Splinting (53%) was the most common treatment reported, followed by pinning (36%) and casting (12.5%). Examination of the burned digit took the longest time and showed the most difference between the sample and the norm scores. When considering the range of motion (ROM) for 5 subjects and were therefore excluded from the summary reports. When compared with norms in both the dominant and nondominant hands, respectively. Among women, the mean grip strength was 18.2kg (normative, 26.9kg) and 14.3kg (normative, 26.5kg) for the dominant and nondominant hands, respectively. The mean pinch strength for men was 6.2kg (normative, 10.7kg) and 5.9kg (normative, 11.6kg) for dominant and nondominant hands, respectively, and for women was 3.3kg (normative, 7kg) and 2.6kg (normative, 7kg) for dominant and nondominant hands, respectively.

The time taken to complete the JTHFT and the sex- and age-based norms for the dominant and the nondominant hands are shown in table 2. Complete JTHFT data were not available for 5 subjects and were therefore excluded from the summary reports. When compared with norms in both the dominant and nondominant hand categories, subjects in this sample took longer to complete the test items. Of the 7 items, writing a sentence took the longest time and showed the most difference between the sample and the norm scores. When considering the dominant hand in the 20 to 59 years of age category, women did better in writing, turning cards, picking up small objects, and moving empty large cans, and men did better with simulating feeding, turning cards, picking up small objects, and moving empty large cans.

The mean grip and pinch strengths for the sample and normative data for the age group are as follows: the mean grip strength for men was 38.8kg (normative, 46.5kg) and 21.6kg (normative, 44.4kg) for the dominant and nondominant hands, respectively. Among women, the mean grip strength was 18.2kg (normative, 26.9kg) and 14.3kg (normative, 26.5kg) for the dominant and nondominant hands, respectively. The mean pinch strength for men was 6.2kg (normative, 10.7kg) and 5.9kg (normative, 11.6kg) for dominant and nondominant hands, respectively, and for women was 3.3kg (normative, 7kg) and 2.6kg (normative, 7kg) for dominant and nondominant hands, respectively.

The following results: with the exception of 1 measurement, all thumb total active motion measurements were less than 180°. The mean ROM appears to be the worst for the right hand thumb (total active motion, 95°), followed by the little finger (142°) on the left hand. The mean total active motion for the index, middle, and ring fingers on the right hand and the middle finger on the left hand ranged between 182° and 195°, which indicates good functional results. However, about 40% of subjects had total active motion scores of below 180° across all other digits.

The total active motion measurements of each digit are shown in table 1. Applying the rating scale as established for tendon injuries of the finger (13% (<180° is considered poor, 180°–219° is good, 220°–259° is excellent, 260° is normal) to the total active motion measurements in this study gave the following results: with the exception of 1 measurement, all thumb total active motion measurements were less than 180°. The mean ROM appears to be the worst for the right hand thumb (total active motion, 95°), followed by the little finger (142°) on the left hand. The mean total active motion for the index, middle, and ring fingers on the right hand and the middle finger on the left hand ranged between 182° and 195°, which indicates good functional results. However, about 40% of subjects had total active motion scores of below 180° across all other digits.

### Table 1: Mean Total Active Motion of the Right and Left Hands

<table>
<thead>
<tr>
<th>Digit</th>
<th>Right Hand</th>
<th>Left Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Total Active Motion</td>
<td>Mean Total Active Motion</td>
</tr>
<tr>
<td>Thumb</td>
<td>95±46</td>
<td>105±43</td>
</tr>
<tr>
<td>Index</td>
<td>183±82</td>
<td>164±98</td>
</tr>
<tr>
<td>Middle</td>
<td>185±84</td>
<td>195±81</td>
</tr>
<tr>
<td>Ring</td>
<td>193±66</td>
<td>167±81</td>
</tr>
<tr>
<td>Little</td>
<td>171±108</td>
<td>142±108</td>
</tr>
</tbody>
</table>

NOTE. Values are mean degrees ± SD.

### Table 2: Time to Complete the Test Items on JTHFT by Age and Sex

#### Dominant Hand

<table>
<thead>
<tr>
<th>Factor</th>
<th>20–59</th>
<th>Norms</th>
<th>60–94</th>
<th>Norms</th>
<th>20–59</th>
<th>Norms</th>
<th>60–94</th>
<th>Norms</th>
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</thead>
<tbody>
<tr>
<td>Age range (y)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. of subjects</td>
<td>11</td>
<td>1</td>
<td></td>
<td></td>
<td>13</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>19±6-8.9</td>
<td>12.2</td>
<td>15.0</td>
<td>19.3</td>
<td>17.5±9.8</td>
<td>11.7</td>
<td>13.7±1.7</td>
<td>15.7</td>
</tr>
<tr>
<td>Cards</td>
<td>9.7±7.2</td>
<td>4.0</td>
<td>5.0</td>
<td>5.3</td>
<td>7.3±5.9</td>
<td>4.3</td>
<td>6.0±1.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Small objects</td>
<td>9.3±4.0</td>
<td>5.9</td>
<td>7.0</td>
<td>6.8</td>
<td>8.9±4.7</td>
<td>5.5</td>
<td>8.0±0.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Simulated feeding</td>
<td>7.8±1.0</td>
<td>6.4</td>
<td>6.0</td>
<td>6.9</td>
<td>11.1±8.5</td>
<td>6.7</td>
<td>13.5±2.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Checkers</td>
<td>6.0±3.5</td>
<td>3.3</td>
<td>4.0</td>
<td>3.8</td>
<td>8.6±10.5</td>
<td>3.3</td>
<td>6.5±7.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Large light objects</td>
<td>6.2±4.5</td>
<td>3.0</td>
<td>6.0</td>
<td>3.6</td>
<td>5.2±1.9</td>
<td>3.1</td>
<td>5.0±0.0</td>
<td>3.5</td>
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<tr>
<td>Large heavy objects</td>
<td>4.8±1.1</td>
<td>3.0</td>
<td>4.0</td>
<td>3.5</td>
<td>7.7±7.0</td>
<td>3.2</td>
<td>4.7±3.5</td>
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#### Nondominant Hand

<table>
<thead>
<tr>
<th>Factor</th>
<th>20–59</th>
<th>Norms</th>
<th>60–94</th>
<th>Norms</th>
<th>20–59</th>
<th>Norms</th>
<th>60–94</th>
<th>Norms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age range (y)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. of subjects</td>
<td>11</td>
<td>2</td>
<td></td>
<td></td>
<td>12</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>33±18.4</td>
<td>32.3</td>
<td>39.0</td>
<td>48.2</td>
<td>33.0±7.7</td>
<td>30.2</td>
<td>31.0±5.6</td>
<td>38.9</td>
</tr>
<tr>
<td>Cards</td>
<td>11.7±7.6</td>
<td>4.5</td>
<td>11±1.4</td>
<td>6.1</td>
<td>8.9±5.5</td>
<td>4.8</td>
<td>9.0±2.8</td>
<td>5.5</td>
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<tr>
<td>Small objects</td>
<td>13.7±8.1</td>
<td>6.2</td>
<td>16±12.7</td>
<td>7.9</td>
<td>12.9±10.9</td>
<td>6.0</td>
<td>11.5±2.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Simulated feeding</td>
<td>13.9±13.8</td>
<td>7.9</td>
<td>13±3.5</td>
<td>8.6</td>
<td>12.2±4.0</td>
<td>8.0</td>
<td>15.7±3.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Checkers</td>
<td>17.2±21.5</td>
<td>3.8</td>
<td>8.5±2.1</td>
<td>3.9</td>
<td>7.1±4.8</td>
<td>3.8</td>
<td>6.0±1.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Large light objects</td>
<td>7.2±3.8</td>
<td>3.2</td>
<td>8.5±2.1</td>
<td>3.9</td>
<td>5.5±1.8</td>
<td>3.3</td>
<td>6.5±0.7</td>
<td>3.4</td>
</tr>
<tr>
<td>Large heavy objects</td>
<td>6.2±2.2</td>
<td>3.1</td>
<td>5.0</td>
<td>3.8</td>
<td>10.0±7.8</td>
<td>3.3</td>
<td>6.2±3.5</td>
<td>3.8</td>
</tr>
</tbody>
</table>

NOTE. Values are mean seconds ± SD as indicated.
lated feeding, stacking checkers, and moving weighted large cans. With the nondominant hand in the same age group, women did better with all test items except moving heavy large cans.

The mean overall score on the MHQ was 63.48. (A score of 100 indicates better hand performance.) Of the 6 components in the MHQ (table 3), subjects reported the most difficulty in performing ADLs, such as turning a door knob, picking up a coin, holding a glass of water, turning a key in a lock, and holding a frying pan. Spearman correlation coefficients indicated a negative correlation between the JTHFT and MHQ (table 4). The time taken to complete the JTHFT activities decreased as the hand function score on the MHQ increased ($P < .01$). Significant negative correlations were found between MHQ ADLs and all tasks of the JTHFT. Similar significant correlations were found between the MHQ work performance score and all tasks of the JTHFT with the exception of feeding. The MHQ hand function negatively correlated ($P < .05$) only with the task of picking up small objects and placing them in a small container and none of the other JTHFT tasks. MHQ pain correlated negatively ($P < .01$) with turning over 3 × 5-in cards, writing a sentence ($P < .05$), and picking up small objects. Also, MHQ aesthetics negatively correlated ($P < .05$) with picking up small objects. There were no significant correlations between MHQ patient satisfaction with hand function and any of the JTHFT tasks. There was a significant negative correlation between MHQ overall score and the task of writing, turning a card, picking up small objects, and moving empty large cans. There was a significant negative correlation between the total score on the JTHFT and the ADLs, pain, and work performance components of the MHQ.

**DISCUSSION**

Burn care providers are aware that hand function is a strong predictor of physical QOL after a massive burn injury. This study was specifically designed to assess the impairments of deep full-thickness hand burns and to compare subjective reports and objective assessments of hand function. Although this sample was not random and likely represented a group of people who are highly motivated to maximize function, the data presented are of value because this is among the first reports to compare objective assessments with subjective reports.

Subjects in this sample had large burns (mean, 58% of TBSA), had long length of hospital stay (mean, 224d), and mostly had lived with their injuries for a number of years (mean, 16y). The sample clearly had very severe hand burns, with more than half of them having amputation of 1 or more digits. The most severe involvement was at the level of the PIP joint, with 50% of the amputations at the PIP joint, and 22% of digits with rupture of the extensor mechanism causing a boutonnière deformity. This was not a surprise finding, because the most commonly exposed joint in the burned hand is the PIP joint, and a boutonnière deformity at the PIP joint is the most common bone and joint defect.

Loss of ROM was a clear impairment in these subjects, who had a mean range of less than 90% total active motion in each digit. Forty percent of subjects had poor functional range with a total active motion of less than 180° (based on the total active motion rating scale). Significant decrease in strength (50% decreases) was seen for measurements of both grip and pinch. This is in contrast to normal pinch and grip strength seen in a study of patients with partial- and full-thickness hand burns. Despite these impairments, this patient population was still quite capable of performing most basic ADL skills. This reinforces a previous study, that showed that less than 9kg of grip strength is sufficient for functional hand use.

Even with partial amputation or loss of the extensor mechanisms, the intact flexor muscles facilitate function by allowing for a modified grasp. At the time of the study, 47% of subjects in this sample reported working full-time. This percentage did not differ significantly from the percentage of people working before burn injury. Therefore, patients with deep full-thickness hand burns are capable of achieving many functional goals. It is clear that patients have significant impairments and functional limitations, but despite these limitations, they are able to perform most daily activities. This is in contrast to full-thickness burns, which have been shown to have “excellent” outcomes and also to the view that deep full-thickness dorsal hand burns do poorly, regardless of the treatment.

On the JTHFT, as expected, subjects were significantly slower ($P < .05$). The time taken to complete the JTHFT activities decreased as the hand function score on the MHQ increased ($P < .01$). Significant negative correlations were found between MHQ ADLs and all tasks of the JTHFT. Similar significant correlations were found between the MHQ work performance score and all tasks of the JTHFT with the exception of feeding. The MHQ hand function negatively correlated ($P < .05$) only with the task of picking up small objects and placing them in a small container and none of the other JTHFT tasks. MHQ pain correlated negatively ($P < .01$) with turning over 3 × 5-in cards, writing a sentence ($P < .05$), and picking up small objects. Also, MHQ aesthetics negatively correlated ($P < .05$) with picking up small objects. There were no significant correlations between MHQ patient satisfaction with hand function and any of the JTHFT tasks. There was a significant negative correlation between MHQ overall score and the task of writing, turning a card, picking up small objects, and moving empty large cans. There was a significant negative correlation between the total score on the JTHFT and the ADLs, pain, and work performance components of the MHQ.

**Table 3: Mean Scores of the MHQ**

<table>
<thead>
<tr>
<th>MHQ Scale</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand function</td>
<td>63±25</td>
</tr>
<tr>
<td>ADLs</td>
<td>56±30</td>
</tr>
<tr>
<td>Work performance</td>
<td>64±32</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>65±27</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>63±27</td>
</tr>
<tr>
<td>Pain</td>
<td>69±26</td>
</tr>
<tr>
<td>MHQ final score</td>
<td>63±23</td>
</tr>
</tbody>
</table>

*NOTE. Values are mean ± SD.*

**Table 4: Correlation Between Time Taken to Complete JTHFT Test Items, Hand Function Measured by MHQ, and Hand Strength**

<table>
<thead>
<tr>
<th>MHQ</th>
<th>JTHFT Test Items</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grip</td>
<td>Pinch</td>
</tr>
<tr>
<td>Hand function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADLs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall MHQ  score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grip strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinch strength</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P < .05.

†P < .01.

moving heavy large cans. Although not scientifically tested, we observed that the women tended to have longer fingernails, which facilitated the fine motor tasks. A further observation was that men with larger hands were able to generate enough grip to lift heavy large cans, whereas most women had to use the palm to flip cans over and over and on to the test board.

A positive correlation of moderate strength between grip strength, work performance, and overall MHQ score found in this study confirmed the findings of Wahi Michener et al. Functionally, subjects reported the most difficulty in performing the MHQ ADL, a component of the MHQ that includes ADLs such as turning a door knob, picking up a coin, holding a glass of water, turning a key in a lock, and holding a frying pan. This replicates the findings of the JTHFT in this sample, with subjects having much more difficulty than population norms. Although hand function has been shown to predict physical QOL, this study did not find a correlation between life satisfaction and hand function. This can be attributed to the fact that satisfaction with life is multifaceted and influenced by the interaction of psychologic and physical variables.

Several MHQ scales, especially the ADL and work performance subscales, and the overall MHQ score correlated with objective assessments of hand function as measured by the JTHFT. Subjects’ perceptions of hand function in this study corresponded with their abilities to actually perform most everyday activities. Therefore, obtaining subjective feedback from patients in addition to an objective evaluation of hand function can be a valuable resource in planning treatment. Physiologic measures such as total active motion and grip and pinch strengths, used along with standardized outcome measures can provide useful information regarding functional outcomes.

Study Limitations

Eighty-six percent of the sample rated their compliance with therapy as excellent or good. It is unknown if the reported compliance had any bearing on the outcomes presented in the study. Further, this study is also limited by its small sample size and lack of treatment information. We were able to provide descriptive information only within a sample and did not compare findings with those of a control group, matched or otherwise. Moreover, because this was a self-selected sample of subjects, we were unable to determine the level of impairment for all participants attending the WBC and who were eligible to participate in the study but chose not to do so.

Twenty-five percent of the study population had joint ankylosis. We were unable to determine if this was a surgical ankylosis (by pinning the joint) or if it had occurred without intervention because of the retrospective nature of these data. We were also unable to ascertain whether ankylosed digits perform more poorly than digits with boutonniere deformity, because many hands had boutonniere deformity, ankylosed digits, and digit amputation. Therefore, we were limited in our efforts to looking at the more general relationship between overall impairment and outcome in the severely burned hand.

The data analysis clearly identified the most significant problem in analyzing data on hand function. Measuring each joint in 2 planes of motion produces an enormous amount of data on a small number of subjects, which significantly reduces the power of the study. We simplified the data by using the total active motion, but this leaves open for criticism the issue of whether a digit with 90° of flexion and −45° of extension can be considered the same as a digit with 45° of flexion and 0° of extension. It is also very difficult to sort by classification of deformity. If a hand has 2 boutonniere deformities and an amputation at the PIP of another digit, is it equivalent to a hand with 2 Swan-neck deformities and a fully amputated thumb?

The answer to this is clearly “no,” but in designing a study of the hand, the number of possible variables is overwhelming, particularly given the relatively low frequency of occurrence. Despite these limitations, the data show that significant impairment was caused by the burn injuries sustained in this sample.

CONCLUSIONS

Although deep full-thickness burn injuries involving the tendons are uncommon and comprise about 5% of hand burns, the impairment associated with this injury is the most significant limitation after a major burn injury. It is also true that the burns of the upper extremity need to be considered in the context of the whole patient. It is evident that hand burns and hand function cannot be evaluated in isolation. The shoulder, axilla, elbow, and wrist play a significant role in determining hand function. It must also be recognized that burn survivors can amazingly compensate for many aspects of this severe impairment. The burn team must be vigilant to salvage viable digits, protect vulnerable extensor mechanisms, and maximize MCP flexion. The next stage in the evaluation of deep full-thickness hand burns is to evaluate the relationship between treatment alternatives and outcomes. This must include pinning versus casting, new interventions with Integra to salvage tendons, and a variety of rehabilitation interventions. Because these injuries are relatively less common, it is essential that well-designed multicenter studies be appropriately funded to facilitate a better understanding of the limitations caused by deep full-thickness dorsal hand burns.

References


Suppliers

a. Sammons Preston, An AbilityOne Company, 4 Sammons Ct, Bolingbrook, IL 60440-4989.

b. SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.
Acute Pain at Discharge From Hospitalization is a Prospective Predictor of Long-Term Suicidal Ideation After Burn Injury

Robert R. Edwards, PhD, Gina Magyar-Russell, PhD, Brett Thoms, PhD, Michael T. Smith, PhD, Radha K. Holavanahalli, PhD, David R. Patterson, MD, Patricia Blakeney, PhD, Dennis C. Lezotte, PhD, Jennifer A. Haythornthwaite, PhD, James A. Fauerbach, PhD


Objective: To determine the extent to which pain contributes to risk for suicidal ideation after burn injury.

Design: This longitudinal cohort study evaluated participants at discharge, 6 months, and 1 year after burn injury.

Setting: Inpatient rehabilitation units of multiple regional burn centers.

Participants: Survivors of major burns (N=128).

Interventions: Not applicable.

Main Outcome Measures: Pain severity, assessed using the Medical Outcomes Study 36-Item Short-Form Health Survey bodily pain subscale, and passive and active suicidal ideation, assessed by self-report.

Results: At each time point, approximately one quarter to one third of the sample reported some form of suicidal ideation. In logistic regression analyses, pain severity at discharge was the sole consistent predictor of suicidal ideation at follow-up, with greater pain severity being associated with enhanced risk for both passive and active suicidal ideation. These associations were observed even after controlling for discharge mental health.

Conclusions: These are the first findings to suggest an association between acute pain severity and the development and maintenance of suicidal ideation in burn patients. Further research in this area, including the study of improved pain management programs as a prophylaxis against suicidal ideation, may benefit those who are at elevated suicide risk as a consequence of burn injuries.

Key Words: Burns; Pain; Rehabilitation; Suicide; Trauma.

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A CONFLUENCE OF RECENT findings from both epidemiologic and clinically based studies strongly suggests that pain is an important risk factor for a constellation of self-injurious behaviors. The presence of persistent pain is associated with elevated rates of suicide-related cognitions and behaviors,14 requests for physician-assisted suicide,1 and completed suicides.8,11 This elevation in suicidality is greater than that observed in other nonpainful physical illnesses,11,12 highlighting the importance of understanding the mechanisms by which the experience of pain influences suicide-related thoughts and behaviors.8 Given that suicide is among the leading causes of death in the United States,13 it is important to understand the factors contributing to the disproportionately high suicide rates among people suffering from pain. In general, rather than focusing on completed suicides, which is almost certain to be rare in any given sample, many researchers evaluate factors contributing to suicidal ideation (SI), a nearly universal correlate of suicidal acts. Because the vast majority of both planned and unplanned suicide attempts occur within 1 year of the onset of SI,14 identification of risk factors for new-onset or worsening SI is of substantial importance. However, one presently unanswered question is to what extent the severity of pain contributes to risk for suicide-relevant outcomes such as SI in patients suffering from painful conditions. For example, although some studies report that suicidal ideation is more common in the context of more severe pain,1,15 other research indicates no association between pain severity and suicidal ideation after controlling for depression.5,16 An important methodologic consideration in such studies is that observed in other nonpainful physical illnesses,11,12 highlighting the importance of understanding the mechanisms by which the experience of pain influences suicide-related thoughts and behaviors.8 Given that suicide is among the leading causes of death in the United States,13 it is important to understand the factors contributing to the disproportionately high suicide rates among people suffering from pain. In general, rather than focusing on completed suicides, which is almost certain to be rare in any given sample, many researchers evaluate factors contributing to suicidal ideation (SI), a nearly universal correlate of suicidal acts. Because the vast majority of both planned and unplanned suicide attempts occur within 1 year of the onset of SI,14 identification of risk factors for new-onset or worsening SI is of substantial importance. However, one presently unanswered question is to what extent the severity of pain contributes to risk for suicide-relevant outcomes such as SI in patients suffering from painful conditions. For example, although some studies report that suicidal ideation is more common in the context of more severe pain,1,15 other research indicates no association between pain severity and suicidal ideation after controlling for depression.5,16 A potentially valuable forum in which to study these associations is in the context of burn injuries, which are often painful, disabling, and disfiguring, and are prospectively associated with high rates of accidental death, including suicides.20 It is interesting to note that although there is substantial and growing literature on psychosocial outcomes after burn injury,21,22 and an equally large number of studies concerning self-inflicted burns as a method for committing suicide,23-26 relatively little research has evaluated the prevalence of suicidal ideation in the postburn period,27 and to our knowledge no studies have evaluated predictors of SI postburn. Two studies28,29 have investigated the link between pain during hospitalization and subsequent psychosocial burn outcomes, but did not consider SI in their analyses. Indeed, the question of whether greater pain severity is an independent risk factor for suicidal ideation has important practical consequences because a variety of interventions have proven effective in managing both acute and chronic pain in other settings,30 though many professionals opt not to use them. Collectively, arguments to convince burn teams to control pain more effectively are needed, and none may be stronger than showing a link between poor pain control and suicides or SI.31,32 At present,
though, whether individual differences in the severity of pain in the acute care setting, in which most people have some degree of pain, can predict suicidal ideation is a crucial yet unanswered question. In the present investigation, we sought to identify whether the severity of pain at discharge was prospectively related to suicidal ideation in patients who had experienced burn injuries. We hypothesized that more severe pain would be associated with greater report of passive and active SI at postdischarge follow-up time points.

METHODS

Participants
Participants were consecutive admissions from 3 regional burn centers in the United States; we recruited patients if they were at least 16 years of age, cognitively competent to provide informed consent, and met American Burn Association criteria for major burn injuries. All participants provided informed consent for a prospective, longitudinal Burn Model Systems (BMS) study sponsored by the National Institute on Disability and Rehabilitation Research. The data reported here were gathered between 1994 and 2000 as part of this larger study. Participants were evaluated at discharge from their acute hospital stay, and then again at 6 and 12 months after burn injury by trained personnel using standard procedures and measures. Several prior studies provide detailed information on the BMS study and the patients who have enrolled. The present sample includes all patients who provided discharge data and also provided data at both the 6-month and 12-month follow-up time points.

A total of 407 patients completed the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) and Brief Symptom Inventory (BSI) at discharge. Of those 407 patients, 207 (50.9%) provided data at the scheduled 6-month postdischarge follow-up. Of those 207 patients, 128 (61.8%) provided data at the 12-month follow-up. Thus, a total of 128 patients provided complete discharge and follow-up data. Interestingly, these 128 patients did not differ from the 279 who did not provide complete follow-up data on demographic or burn-related characteristics (age, sex, burn area), on discharge SI, or discharge scores on the SF-36 bodily pain, general health, or mental component subscales (all P > 0.05).

Of the 128 “completers,” 70.3% were men, consistent with a typical preponderance of men among burn survivors. In addition, the sample was largely white (77.3%), with an average age of 40.6 ± 15.0 years. The etiology of the burn injuries was generally flame (57.0%), contact (25.0%), or electrical (20.0%). The most commonly affected anatomic sites in this sample were the arm (67.2%), hand (58.7%), and trunk (53.4%); many patients were burned at multiple sites. In terms of burn severity, the mean total body surface area (TBSA burned) was 18.7%, and mean total body surface grafts (TBSA grafted) was 9.6%.

Measures

Demographic and injury-related variables. Patient demographics (race, age, sex) were evaluated by self-report as part of the standard history and physical on admission to the burn center. In addition, multiple aspects of a patient’s injury were recorded, including the total body surface area affected by burn injury (TBSA burned), and the total body surface area on which skin grafts were performed (TBSA grafted).

SF-36. The SF-36 is a 36-item measure of quality of life that includes composite or summary scales reflecting patient-reported physical, psychologic, and social health and function. The SF-36 is the most widely used health status measure in the world; it possesses excellent psychometric properties across a wide variety of patient and nonpatient samples. Two subscales and component scale of the SF-36 were used as measures of pain, general health, and psychosocial function. The bodily pain and general health subscales provide scores from 0 (eg, very poor health and extremely severe pain) to 100 (optimal health and no pain), which characterize levels of pain and perceived overall health over the past 4 weeks. The SF-36 mental component scale (MCS) is a summary of 4 additional subscales: mental health, social functioning, role interference from emotional problems, and vitality. Patients completed the SF-36 at 4 different time points: the first was during their hospital stay, in reference to their preinjury functioning, the second was at discharge in reference to their current functioning, the third was at 6-month follow-up, and the fourth was at 12-month follow-up.

Brief Symptom Inventory. The BSI is a short form of the Symptom Checklist-90–Revised. It assesses psychologic symptomatology over the past week across a range of domains. As in prior studies, we used responses to 2 BSI items to classify the reported degree of suicidal ideation (see Classification of Suicidality section below). Patients completed the BSI at discharge and 6-month and 12-month follow-up points.

Classification of Suicidality

We classified the presence and degree of suicidal ideation using questionnaire items as in previous studies of pain and suicide. Although this method is not ideal (ie, a clinical interview and complete suicide questionnaire would be preferable), an earlier study of chronic pain patients comparing the use of a single questionnaire item with results from a semi-structured interview revealed reasonable convergence between these 2 assessment methods.

In the present study, items 9 and 39 on the BSI (for an example, see Edwards et al) were used to classify subjects into 1 of 3 categories at each study time point: (1) no self-reported SI (ie, scores of zero on each item), (2) self-reported passive SI (ie, non-zero score on BSI item 39 [thoughts of death or dying] but a score of zero for BSI item 9 [thoughts of ending your life]), and (3) self-reported active SI (ie, a non-zero score on BSI item 9 [thoughts of ending your life]). In effect, this category of “active SI” could be labeled “both active and passive SI” because over 90% of those who report active SI also report passive SI. The specified time frame for these self-report items was “over the past week. . . .”

Data Reduction and Analysis

We conducted analyses examining pain as a prospective predictor of SI in 2 ways. First, as a more conceptually simple method, subjects were categorized according to their course of SI from discharge to 1-year follow-up. The following 4 mutually exclusive and exhaustive classifications were used: (1) “No SI,” approximately 52% of the sample, included subjects who reported no SI at any study time point; (2) “Develop any SI,” approximately 20% of the sample, included subjects with no SI at discharge who subsequently reported passive or active SI at follow-up; (3) “Persisting or Worsening SI,” approximately 17% of the sample, included those who reported SI at discharge, and who continued to report the same or a greater degree of SI out to 1 year follow-up; and (4) “Resolving or Improving SI,” just over 10% of the sample, included subjects who reported SI at discharge but whose SI was either reduced (ie, from active SI to passive SI) or absent at follow-up. Analysis of variance (ANOVA) was used to compare discharge bodily pain scores in these 4 groups, with follow-up contrasts to determine the nature of group differences.
Abbreviation: ND, no data.

mental health, less pain, etc.

### RESULTS

Patients’ estimates of preburn pain suggested mild pain, on average, prior to injury (mean preburn SF-36 bodily pain score, 85.5); at discharge, the mean SF-36 bodily pain score for the sample was 33.7 (note that the SF-36 bodily pain subscale yields scores from 0 to 100 where 100 indicates no pain and 0 indicates very severe, disabling pain), reflecting a moderate to severe degree of pain (Table 1). At 6- and 12-month follow-up, pain severity had substantially decreased (represented by higher SF-36 bodily pain scores) compared with discharge levels. Correlations between pain reports at each study time point are presented in Table 2. Rates of suicidal ideation at discharge and follow-up are presented in Table 1; generally, rates of SI were fairly stable at a group level across the duration of the study, with one quarter to one third of patients reporting some form of SI. Despite this stability at the group level, however, many participants varied in SI over the course of the study. See figure 1 for the percentage of patients with particular courses of SI. When reduced to the 4 categories described above, approximately 52% of the sample reported no SI at any study time point, nearly 20% of the sample had no SI at discharge but later developed SI, around 17% of the sample reported persistent or worsening SI from discharge to 1-year follow-up, and just over 10% of the sample described SI that improved or resolved from discharge to follow-up.

#### Predicting the Course of SI

An ANOVA comparing the 4 groups described above on discharge bodily pain scores revealed a significant omnibus effect (F3,125 = 5.3, *p* < .01), indicating at least some group difference. Follow-up univariate contrasts revealed that the “No SI” group and the “Resolving or Improving SI” group reported significantly less pain at discharge (*p* < .01, *p* < .05, respectively) than the “Persisting or Worsening SI” group (fig 2). The group of participants who developed SI had lower mean scores than the “No SI” and “Resolving or Improving SI” groups, but these differences did not approach statistical significance.

#### Logistic Regressions

In univariate analyses, worse general health at discharge, higher pain severity at discharge, lower MCS scores at discharge, lower preburn MCS score, and female sex were associated with a higher probability of reporting SI at discharge (all

### Table 1: SF-36 Bodily Pain and MCS Scores and Classification of Suicidal Ideation at Each Study Time Point

<table>
<thead>
<tr>
<th>Scores and Classifications</th>
<th>Preburn</th>
<th>Discharge</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-36 bodily pain</td>
<td>85.5±22.2</td>
<td>33.7±23.9</td>
<td>61.1±28.3</td>
<td>64.8±28.6</td>
</tr>
<tr>
<td>SF-36 MCS</td>
<td>51.1±12.1</td>
<td>44.3±13.4</td>
<td>45.3±14.7</td>
<td>45.4±14.1</td>
</tr>
<tr>
<td>No SI</td>
<td>ND</td>
<td>95/128 (74.2)</td>
<td>94/128 (73.4)</td>
<td>87/128 (68.0)</td>
</tr>
<tr>
<td>Thoughts of death</td>
<td>ND</td>
<td>21/128 (16.4)</td>
<td>19/128 (14.8)</td>
<td>22/128 (17.2)</td>
</tr>
<tr>
<td>Active SI</td>
<td>ND</td>
<td>12/128 (9.4)</td>
<td>15/128 (11.7)</td>
<td>19/128 (14.8)</td>
</tr>
</tbody>
</table>

*Note. Values are mean ± standard deviation (SD) and n/N and percent. SF-36 scores are calculated such that higher scores reflect better mental health, less pain, etc. Abbreviation: ND, no data.

#### Table 2: Intercorrelations Among SF-36 Bodily Pain Scores at Each Study Time Point

<table>
<thead>
<tr>
<th>Time Point</th>
<th>Preburn</th>
<th>Discharge</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preburn</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>.13</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>.15</td>
<td>.30*</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>.17**</td>
<td>.22†</td>
<td>.68‡</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*P < .05; †P < .01; ‡P < .001.
PAIN AND SUICIDAL IDEATION, Edwards

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Table 3: SF-36 Bodily Pain Scores at Each Study Time Point as a Function of Discharge SI Status

<table>
<thead>
<tr>
<th>SI Status</th>
<th>Preburn</th>
<th>Discharge</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SI at discharge</td>
<td>87.9±20.7</td>
<td>37.4±25.4</td>
<td>63.9±26.2</td>
<td>70.0±30.5</td>
</tr>
<tr>
<td>PSI at discharge</td>
<td>80.8±23.7</td>
<td>35.1±26.7</td>
<td>63.3±28.7</td>
<td>65.2±27.0</td>
</tr>
<tr>
<td>ASI at discharge</td>
<td>79.3±24.0</td>
<td>16.9±13.5</td>
<td>37.3±25.2</td>
<td>49.5±28.7</td>
</tr>
</tbody>
</table>

*NOTE. Values are mean ± SD. SF-36 scores are calculated such that higher scores reflect better mental health, less pain, etc. Abbreviations: ASI, active suicidal ideation (thoughts of ending your life); PSI, passive suicidal ideation (thoughts of death or dying).*

Table 4: Multivariate Predictors of SI at Discharge

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted OR No SI vs PSI</th>
<th>Adjusted OR No SI vs ASI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBSA burned</td>
<td>1.02</td>
<td>0.97</td>
<td>.68</td>
</tr>
<tr>
<td>TBSA grafted</td>
<td>0.98</td>
<td>1.02</td>
<td>.75</td>
</tr>
<tr>
<td>Minority race</td>
<td>0.74</td>
<td>0.48</td>
<td>.69</td>
</tr>
<tr>
<td>Female sex</td>
<td>0.33</td>
<td>6.00</td>
<td>.01</td>
</tr>
<tr>
<td>Age</td>
<td>0.98</td>
<td>0.98</td>
<td>.46</td>
</tr>
<tr>
<td>Preburn SF-36 MCS</td>
<td>1.01</td>
<td>0.73</td>
<td>.60</td>
</tr>
<tr>
<td>Preburn SF-36 bodily pain</td>
<td>0.84</td>
<td>0.98</td>
<td>.40</td>
</tr>
<tr>
<td>Discharge SF-36 general health</td>
<td>0.96</td>
<td>0.80</td>
<td>.58</td>
</tr>
<tr>
<td>Discharge SF-36 MCS</td>
<td>0.57</td>
<td>0.64</td>
<td>.06</td>
</tr>
<tr>
<td>Discharge SF-36 bodily pain</td>
<td>0.99</td>
<td>0.65</td>
<td>.22</td>
</tr>
</tbody>
</table>

*NOTE. Likelihood ratio test for final model: $\chi^2$ test = 41.4, $P = .003$, $R^2 = .36$. All SF-36 adjusted odds ratios (ORs) are indexed to a 10-point change. For example, an adjusted OR of .65 for the SF-36 bodily pain score, for the comparison of No SI with ASI, would reflect a 35% decrease in the probability of ASI relative to no SI for every 10-point increase in the SF-36 bodily pain score.*
burned and TBSA grafted, and patients’ estimates of their general health at discharge, were not predictive of SI in any of the models. Although poor health is a clear risk factor for SI in the general population,22,23 these findings suggest that injury severity and perceived physical health (at discharge) in the context of a burn injury are not strong determinants of SI. Similarly, depression is among the most robust correlates of suicidal behavior in the suicide literature.43 In the present study, in the multivariate models which included pain severity, the SF-36 MCS (a general measure of psychologic health and function) at discharge was unrelated to SI. That is, assessing global mental health at discharge did not provide, in this sample, significant information about future risk of suicidal ideation.

In contrast, pain severity was the most robust discharge risk factor for SI. This was the central finding of this study, one which has not previously been examined in the context of burn injury. Prior investigations of the relationship between pain severity and SI in the context of chronic pain have been mixed, with some reports documenting a positive relationship,1,15 and others finding none.5,16 Recent studies of conditions that may or may not include pain as a concomitant have indicated that the degree of physical pain reported in the context of conditions such as high levels of neuroticism or personality disorders then facilitate SI. Finally, pre-existing, stable characteristics such as post-high levels of neuroticism or personality disorders might also serve as risk factors both for elevated report of pain severity,56,57 and for the development or worsening of SI after an acute injury such as a burn.

In attempting to explain the relationship between pain and suicidal ideation, it is useful to discuss some similar studies done on the relationship between burn pain and distress after hospitalization. Pateck et al58 developed a composite score of pain during wound care during hospitalization and investigated how well it predicted distress as measured by the BSI at 1 month postdischarge. Pain during hospitalization had a stronger correlation with distress than did the size of the burn injury, the length of hospitalization, or any other variable that was investigated. More recently, Patterson et al59,60 reported that such composite scores of pain were the strongest predictors of post-traumatic stress disorder, distress, and health-related quality of life at 1- and 1-year follow-up. Clearly, pain is among the strongest long-term predictors of distress and quality of life, as well as suicidal ideation.

### Study Limitations

Several limitations of this study should be considered in interpreting the findings. First, the methodology relied on paper-and-pencil measures of SI, but a clinical interview is considered the criterion standard for assessment of suicidality.58 Second, we obtained no formal psychiatric diagnoses, which might have allowed more refined prediction of SI. Third, several variables that have been identified as important contribu-

---

**Table 5: Multivariate Predictors of SI at 6 Months Postdischarge**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted OR</th>
<th>Adjusted OR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI at discharge</td>
<td>5.94</td>
<td>3.67</td>
<td>.01</td>
</tr>
<tr>
<td>TBSA burned</td>
<td>1.01</td>
<td>1.04</td>
<td>.56</td>
</tr>
<tr>
<td>TBSA grafted</td>
<td>0.92</td>
<td>0.90</td>
<td>.08</td>
</tr>
<tr>
<td>Minority race</td>
<td>1.44</td>
<td>1.06</td>
<td>.39</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.28</td>
<td>2.96</td>
<td>.05</td>
</tr>
<tr>
<td>Age</td>
<td>0.99</td>
<td>0.93</td>
<td>.20</td>
</tr>
<tr>
<td>Preburn SF-36 MCS</td>
<td>1.35</td>
<td>0.71</td>
<td>.23</td>
</tr>
<tr>
<td>Preburn SF-36 bodily pain</td>
<td>1.36</td>
<td>0.84</td>
<td>.10</td>
</tr>
<tr>
<td>Discharge SF-36 general health</td>
<td>0.87</td>
<td>0.97</td>
<td>.74</td>
</tr>
<tr>
<td>Discharge SF-36 MCS</td>
<td>0.88</td>
<td>0.75</td>
<td>.69</td>
</tr>
<tr>
<td>Discharge SF-36 bodily pain</td>
<td>0.95</td>
<td>0.40</td>
<td>.002</td>
</tr>
</tbody>
</table>

Parameters after insertion of concurrent pain into the model

Concurrent (6mo) SF-36 bodily pain | 1.00        | 0.57        | .004 |

Discharge SF-36 bodily pain | 0.95        | 0.33        | .001 |

**Note.** Likelihood ratio test for final model: $\chi^2 = 60.8, P < .001, R^2 = .48$: All SF-36 adjusted ORs are indexed to a 10-point change.

### Table 6: Multivariate Predictors of SI at 1 Year Postdischarge

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted OR</th>
<th>Adjusted OR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI at discharge</td>
<td>2.07</td>
<td>3.64</td>
<td>.11</td>
</tr>
<tr>
<td>TBSA burned</td>
<td>1.01</td>
<td>1.01</td>
<td>.93</td>
</tr>
<tr>
<td>TBSA grafted</td>
<td>0.99</td>
<td>1.00</td>
<td>.96</td>
</tr>
<tr>
<td>Minority race</td>
<td>0.94</td>
<td>1.38</td>
<td>.88</td>
</tr>
<tr>
<td>Female sex</td>
<td>0.70</td>
<td>2.92</td>
<td>.15</td>
</tr>
<tr>
<td>Age</td>
<td>1.02</td>
<td>0.98</td>
<td>.45</td>
</tr>
<tr>
<td>Preburn SF-36 MCS</td>
<td>0.80</td>
<td>0.65</td>
<td>.25</td>
</tr>
<tr>
<td>Preburn SF-36 bodily pain</td>
<td>1.12</td>
<td>1.02</td>
<td>.70</td>
</tr>
<tr>
<td>Discharge SF-36 general health</td>
<td>1.13</td>
<td>1.01</td>
<td>.70</td>
</tr>
<tr>
<td>Discharge SF-36 MCS</td>
<td>1.01</td>
<td>1.04</td>
<td>.98</td>
</tr>
<tr>
<td>Discharge SF-36 bodily pain</td>
<td>0.77</td>
<td>0.77</td>
<td>.04</td>
</tr>
</tbody>
</table>

Parameters after insertion of concurrent pain into the model

Concurrent (12mo) SF-36 bodily pain | 0.88        | 0.62        | .001 |

Discharge SF-36 bodily pain | 0.80        | 0.77        | .09  |

**Note.** Likelihood ratio test for final model: $\chi^2 = 38.9, P < .05, R^2 = .29$: All SF-36 adjusted ORs are indexed to a 10-point change.
tors to SI were not measured in the present study, including family history of suicidal behavior. Moreover, in future studies it would be desirable to classify participants according to whether the burns were self-inflicted, which might certainly have implications for future SI risk. Fourth, although the pain being reported was “due to the burn,” the specific source of the pain which patients were reporting was not clear (eg, pain directly attributable to the burn injury, pain due to infections, pain due to surgical procedures or débridement), and this will be an important factor to assess in future studies. Fifth, although the sample size in the present study appears reasonable, there was a significant degree of dropout over the course of the study, raising questions about the generalizability of the findings. Finally, as noted above, we do not have data on the specific mechanisms by which pain prospectively influences SI.

CONCLUSIONS

This investigation is the first to rigorously evaluate interrelationships between pain and SI in the context of burn injury. These data underscore the importance of assessing and treating pain after acute traumatic injuries, and suggest that interventions designed to reduce pain and teach adaptive coping skills may have important benefits in terms of lowering suicide risk in rehabilitative and post-rehabilitative settings after burn injuries.

References

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Factors Influencing the Efficacy of Virtual Reality Distraction Analgesia During Postburn Physical Therapy: Preliminary Results from 3 Ongoing Studies

Sam R. Sharar, MD, Gretchen J. Carrougher, RN, MN, Dana Nakamura, OT, Hunter G. Hoffman, PhD, David K. Blough, PhD, David R. Patterson, PhD


Objective: To assess the efficacy and side effects of immersive virtual reality (VR) distraction analgesia, as well as patient factors associated with VR analgesic efficacy in burn patients who require passive range-of-motion (ROM) physical therapy (PT).

Design: Prospective, randomized, controlled, within-subject trials.

Setting: Regional level I burn center in a university-affiliated urban hospital.

Participants: Patients (age range, 6–65 y) who required passive ROM PT in sessions lasting 3 to 15 minutes after cutaneous burn injury.

Interventions: Standard analgesic (opioid and/or benzodiazepine) care and standard analgesic care plus immersive VR distraction.

Main Outcome Measure: Self-reported subjective pain ratings (0 to 100 graphic rating scale).

Results: A total of 146 treatment comparisons were made in 88 subjects, 75% of whom were children ages 6 to 18 years. Compared with standard analgesic treatment alone, the addition of VR distraction resulted in significant reductions in subjective pain ratings for worst pain intensity (20% reduction), pain unpleasantness (26% reduction), and time spent thinking about pain (37% reduction). Subjects’ age, sex, ethnicity, size of initial burn injury, or duration of therapy session did not affect the analgesic effects of VR distraction. Nausea with the standard care plus VR distraction condition was infrequent (15%) and mild, with 85% of the subjects reporting no nausea. Children provided higher subjective reports of “presence” in the virtual environment and “realness” of the virtual environment than did adults, but age did not affect the analgesic effects of VR distraction.

Conclusions: When added to standard analgesic therapy, VR distraction provides a clinically meaningful degree of pain relief to burn patients undergoing passive ROM PT. Multiple patient factors do not appear to affect the analgesic effect. Immersive VR distraction is a safe and effective nonpharmacologic technique with which to provide adjunctive analgesia to facilitate patient participation in rehabilitation activities.

Key Words: Analgesia; Burns; Pain; Physical therapy techniques; Rehabilitation; Virtual systems.

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ATIENTS WITH SEVERE cutaneous burn injuries require comprehensive care, including daily wound care, surgical skin grafting, nutritional support, and coordinated rehabilitation therapy. Aggressive physical therapy (PT) is of particular value to victims of significant extremity burns in efforts to increase the flexibility and elasticity of healing skin (native or grafted), and to help maintain normal extremity range of motion (ROM) and function. Without daily PT, the normal healing process in burn-injured skin may result in contractures and reduced joint ROM secondary to hypertrophic scarring.1,2 Thus, successful participation in such rehabilitation activities is often crucial to minimizing long-term disability. Unfortunately, the pain and anxiety associated with PT can discourage burn patients from participation3 and can lead to such additional morbidity as permanent reduction in limb mobility, or to a need for further surgery. Because procedural pain often cannot be adequately managed with pharmacologic analgesics alone (eg, opioids), in large part because of intolerable side effects (eg, opioid-induced sedation and respiratory depression),4 these patients are aggressively treated with both pharmacologic and nonpharmacologic analgesic techniques.5 Several nonpharmacologic, psychologic techniques have been used alone or as adjuncts to opioid analgesics6 to reduce pain during brief procedures such as postburn PT. Cognitive distraction (eg, listening to music, watching a movie) is one psychologic technique that favorably alters pain perception.7

Immersive virtual reality (VR) is a particularly attention-grabbing distraction technique that is designed to give users the illusion of going inside a computer-generated virtual environment. VR appears to provide significant cognitive distraction because it is interactive, it utilizes a head-mounted display that blocks from the user visual and aural input from the immediate medical care environment, and it places significant cognitive demand on patients through the provision of multisensory input (visual, aural, and sometimes tactile). Thus, VR commands the user’s attention and may exert its analgesic effect by diverting conscious attention away from concurrent nociceptive stimulation, resulting in an attenuated subjective pain experience. Adjunctive, immersive VR distraction has provided clinically meaningful pain relief (at least 33% reductions in subjective pain scores8) compared with standard care (eg, opioid analgesia alone, with or without lesser forms of cognitive distraction) in
different clinical procedural pain settings, including burn wound débridement, postoperative PT, prostate thermosurgery, and dental procedure pain. Similarly, VR distraction has been reported to reduce pain and nausea, and enhance comfort in patients undergoing brief cancer-related procedures and in cancer chemotherapy.

Specific to the setting of postburn PT, immersive VR distraction has been an effective analgesic in 2 preliminary studies exploring single therapy sessions and multiple, serial therapy sessions. Both studies, however, were constrained by the small numbers of subjects (a total of 19 subjects), which limits the generalizability of VR analgesic efficacy and side effects to larger populations of burn patients, and also limits the ability to determine potential associations between efficacy and patient age, sex, race, or other factors. Our goal in this study was to assess the efficacy and side effects of VR distraction analgesia, and to determine what patient factors, if any, are associated with VR analgesic efficacy, in a larger sample of burn patients who require passive ROM (PROM) PT.

METHODS

Participants

Study patients were recruited from the daily inpatient census of the regional level I burn center for the 5-state Pacific Northwest region of the United States, located in Seattle. Eligible patients were between 6 to 65 years of age and who required postburn PT consisting of PROM exercises on at least 1 occasion during their hospital stay. Participation was voluntary, and subjects were not reimbursed for their participation. Informed written consent (and parent/guardian assent for children) was obtained using protocols reviewed and approved by the institutional human subjects review board.

Study Design

To maximize the number of participants in order to meet the study’s goal, we pooled data from 3 ongoing, separate studies of the application of immersive VR distraction analgesia for postburn PT. None of the 3 studies has been completed, summarized, or submitted for publication. Taken individually, none will have sufficient sample size to meet this study’s goal, but by combining their data our goal will be met. No patient was enrolled in more than 1 study.

The protocols for the 3 studies were identical in the following ways: (1) each subject was assigned the same therapist for all exercise sessions, (2) the maximum duration of the therapy session was 15 minutes, and (3) all studies used a within-subject design that compared subjective pain ratings between “standard care” and the “standard care plus VR distraction,” thereby controlling for each subject’s pre-procedure pharmacologic analgesic therapy (not controlled by the investigators). The protocols differed slightly, however, in the age range of the study populations and the number of PT sessions. Details of each study protocol are provided below and summarized in Table 1.

**Study 1.** Subjects were ages 21 to 65 years who required PROM exercises of 1 or more joints during 1 daily PT session that was repeated in an identical fashion on 2 consecutive days. Subjects received standard analgesic care (systemic opioid and/or benzodiazepine medication) on 1 day, and identical standard analgesic care plus VR distraction on the other day, with the order of treatments randomized by a random number generator. Self-reported subjective assessments of pain, nausea (VR condition only), “realness” of the virtual environment (VR condition only), and sense of “presence” in the virtual environment (VR condition only) were recorded immediately after each treatment session with 100-mm graphic rating scales (GRSs) (see below).

**Study 2.** Subjects were ages 6 to 18 years who required PROM exercises of 1 or more joints during a single PT session performed on 1 day. Subjects received standard analgesic care (systemic opioid and/or benzodiazepine medication) before the session, which was divided into 2 components corresponding to the intervention conditions of standard analgesic care with or without VR distraction that were identical in both duration and content. VR was not administered during 1 of the session components but was during the second component, with the order of treatments randomized, again by random number generator. Self-reported subjective assessments were identical to those described for study 1.

**Study 3.** Subjects were ages 6 to 19 years who required PROM exercises daily of 1 or more joints in 2 or more consecutive PT sessions. Subjects received standard analgesic care (systemic opioid and/or benzodiazepine medication) before each session, with the session divided into 2 components identical in both duration and content. VR was not administered during 1 of the components but was during the other component, with the order of treatments randomized, also by random number generator, and counterbalanced. Subjective assessments were identical to those described for study 1.

Although standard analgesic care was individualized and often differed among the subjects, the within-subject study design provided for pharmacologic analgesia that was identical (drug and dose) for each subject in both the control (no VR)
World on the Windows 2000 operating system. We used a GeForce 6800 video card running the VR software Snowsation with dual 2GHz central processing units, 2GB of RAM, a familiarize the patient with how to navigate the virtual environment experienced by subjects when in immersive VR. Reprinted with permission. Image by Stephen Dagadakis. ©Hunter Hoffman, University of Washington.

Fig 1. User's view of SnowWorld, the 3-dimensional virtual environment experienced by subjects when in immersive VR. Reprinted with permission. Image by Stephen Dagadakis. ©Hunter Hoffman, University of Washington.

and VR distraction conditions. Because the standard analgesic care was controlled, and because the PT sessions were identical (in both content and therapist) under both study conditions, the dependent outcomes assessed reflect the specific effect of the VR distraction intervention.

Study Protocol

The typical PT session consisted of slow, gentle stretching of the selected extremity to end range of the affected joint in all possible planes of movement. When more than 1 joint was involved, the proximal joint was ranged first, followed by the distal joint(s). The same assisted PROM exercises were performed during both experimental conditions for each patient (ie, same exercises performed in the same plane[s], same number of repetitions, and same duration of stretch time). Treatment sessions in both study conditions were timed (maximum, 15min) to ensure that both sessions were of equal duration for a given patient. Although the order of the 2 interventions was randomized (ie, each treatment condition had an equal chance of occurring first or second for each patient), joint ranging in the VR condition was always preceded by helmet placement and a brief (1–2min) orientation period to familiarize the patient with how to navigate the virtual environment.

The VR system consisted of a personal computer workstation with dual 2GHz central processing units, 2GB of RAM, a GeForce 6800 video card running the VR software SnowWorld on the Windows 2000 operating system. We used a Polhemus Fastrak position tracking system to monitor the position of the user’s head. While in immersive VR SnowWorld, subjects followed a predetermined path, "gliding" through an icy 3-dimensional virtual canyon. Subjects aimed with their gaze direction (head orientation) and pushed a keyboard button to shoot virtual snowballs at virtual snowmen, igloos, robots, and penguins (fig 1).

The VR condition included head tracking (eg, subjects saw the sky when they looked up, a canyon wall when they looked to the left or right, a river when they looked down), sound effects (eg, a splash when a snowball hit the river), and animated green, blue, or white colored explosions. Subjects wore the nVisor SX high-resolution, head-mounted display, which completely blocked their view of the immediate, real world, medical care environment. This helmet has a 60° diagonal field of view for each of the 2 eyepieces, and a resolution of 1280×1024 pixels per eye (2 eyes = 2,621,440 pixels total). The head-mounted display included stereophonic sound consisting of background music, intermittently joined by sounds of snowball shooting, snow splashing in the virtual river, and other sound effects.

Immediately after each therapy session (study 1) or component session (studies 2 and 3), subjects were asked to provide subjective ratings of 3 separate pain outcomes, as well as the “fun” they had during the session (studies 2 and 3 only), using the 0- to 100-labeled GRSs. Specifically, subjects rated the amount of time spent thinking about pain (cognitive pain dimension), pain unpleasantness (affective pain dimension), and worst pain intensity (sensory pain dimension) they experienced during the preceding therapy session. Such pain rating scales are valid through their strong associations with other measures of pain intensity, as well as their ability to detect treatment effects. Cognitive, affective, and sensory pain are separately measurable and are often differentially influenced components of the pain experience, and such ratio scale measures have reliably assessed these subjective pain outcomes.

Figure 2 shows an example of one such labeled GRS. In addition, after every therapy session performed in the VR condition, subjects were asked to provide subjective ratings (using GRSs) of any nausea they experienced (to assess for potential simulator sickness), the perceived “realness” of the virtual environment, and the degree to which they felt “present” in that environment. VR presence is a subjective illusion created by sensory input in the user’s mind and can be assessed by 1-dimensional or multidimensional rating scales.

Data Analysis

To take advantage of the within-subjects study design (each subject serving as his/her own control), we used regression models that accounted for the longitudinal nature of the data to assess all outcomes. Specifically, to account for correlations among repeated measures on the subjects, generalized estimating equations were used to obtain valid standard errors of model parameter estimates. We used separate regression models for each of the dependent variables (time spent thinking about pain, pain unpleasantness, worst pain intensity, nausea, fun, VR realism, VR presence). The independent variables were categorical in nature and included the primary intervention (standard care, standard care plus VR distraction), and the demographic variables of sex, age (6–18 y, 19–65 y), and ethnicity (white, nonwhite). We used dummy variables to represent these in the regression models. Interaction terms were included as products of the dummy variable for VR and the demographic dummy variables. We assessed potential effect modification (interaction) of patient factors on VR analgesia.

How much TIME did you spend thinking about your pain during this most recent session?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>None of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Some of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All of</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 2. Example of a GRS used for subjective pain assessment by subjects; in this example, the subject is assessing the cognitive dimension of the pain experience (time spent thinking about pain).
using the same models. We also used linear regression models for outcomes measured only in the VR distraction condition (nausea, VR realness, VR presence).

All statistical analyses were performed using SAS, and comparisons differing at the level of \( P < 0.05 \) were considered significant.

### RESULTS

Eighty-eight subjects (74 males, 14 females) aged 6 to 65 years completed the study. Because 26 subjects in study 3 were studied under both treatment conditions (standard care, standard care plus VR) on more than 1 day (range, 2–7 days), the final dataset included a total of 146 within-subjects comparisons between the standard care and the standard care plus VR distraction conditions. Table 2 shows the demographics of the study population and the population of comparisons. The majority of subjects (84%) and comparisons (82%) were male, a sex predominance in the study population that reflects burn injury survivor demographics in the United States in general (70%).

Eighty-eight subjects (74 males, 14 females) aged 6 to 65 years completed the study. Because 26 subjects in study 3 were studied on multiple occasions (range, 2–7 days), resulting in a total of 146 treatment comparisons among the 88 study subjects.

The subjective pain and fun scores for the entire cohort of study subjects (n = 146 comparisons) are summarized in Table 3. User assessments of both VR distraction to standard analgesic care resulted in significant improvements in pain reports, including a mean reduction of 20% across the entire comparison group for worst pain intensity, 26% for pain unpleasantness, and 37% for time spent thinking about pain. The amount of fun that subjects reported experiencing during the therapy session increased 4-fold with the addition of VR distraction. Of the significant improvements observed in all 3 pain outcome measures with the addition of VR distraction to standard care, none were affected by age (≤18y vs ≥19y), sex, ethnicity (white vs nonwhite), initial burn size, or duration of therapy session (3–5 min vs 6–15 min).

The 3 outcomes assessed only in the VR distraction condition (nausea, user assessment of realism of the virtual environment, user assessment of presence in the virtual environment) are summarized in Table 4. User assessments of both realism of, and presence in, the virtual environment were affected only by age of subjects, with younger subjects (6–18y) reporting significantly higher ratings for SnowWorld realism and presence than adult subjects (19–65y). Despite these age-dependent differences in the virtual environment experience, however, there were no age-dependent differences in subjective pain ratings in the VR distraction condition. Eighty-five percent of participants rated nausea in the standard care plus VR condition as zero. The remaining 15% reported only mild nausea, with a mean subjective magnitude of 15 (0–100 GRS assessment). Nausea ratings were not affected by age, sex, ethnicity, initial burn size, or duration of therapy session.

### DISCUSSION

Rehabilitation activities, including PT and occupational therapy, are integral components of today’s comprehensive treatment approach to patients with major burn injuries. Specifically, PROM PT, by maintaining skin elasticity and flexibility, is beneficial in preventing hypertrophic scarring, contractures, and reduced joint mobility that are often secondary complications resulting from normal healing mechanisms in burn-injured skin. Such therapy sessions begin as soon as possible after the initial injury and require daily repetition for periods of weeks to months to prevent complications of immobility. The pain that patients experience during these therapy sessions is significant, repeated, challenging to treat, and is also a determinant of how patients will cooperate and participate in the rehabilitation plan.

Early analgesic interventions in the inpatient burn care setting usually involve systemic opioids and/or anxiolytics; however, unintended side effects of these medications, as well as a desire to minimize such agents before hospital discharge, may limit their use. As a result, nonpharmacologic behavioral interventions such as cognitive distraction and behavioral modification, are valuable analgesic adjuncts in the treatment of burn-related rehabilitation pain. Preliminary reports suggest...
that distraction with immersive VR may have both analgesic and functional outcome benefits in this specific setting, as well as in nonburn settings, such as postoperative PT. Published reports of VR distraction analgesia in these and other medical care settings have been severely limited by their small sample sizes. As a result, little is known about the generalizability of these preliminary results, or of the potential interaction effects of various patient factors such as age, sex, and ethnicity on the reported analgesia.

We conducted this study to address these shortcomings by assessing the analgesic efficacy and other factors associated with VR distraction in a significantly larger population, including a wider range of subjects, than previously reported. A within-subjects design permitted the specific assessment of VR distraction analgesia while controlling for individualized and varying pharmacologic analgesic dosing that necessarily occurs in the clinical setting. Our principal finding was that VR distraction, when added to standard analgesic care, resulted in statistically significant and/or clinically significant (defined as at least 33% or greater) reductions in subjective pain reports for 3 complementary dimensions of the pain experience (sensory, emotional, and cognitive pain). The magnitude and direction of the VR analgesic effect were consistent with those reported in previous pilot studies in the same burn PT setting.

Regarding the potential application of VR analgesic techniques to varying patient populations, we found the analgesic effect of VR distraction to be maintained irrespective of patient age, sex, and ethnicity. These findings of potential wide applicability are consistent with VR analgesia investigations in experimental pain settings, including the independence of analgesic effect on sex and on hypnotizability. In addition, patients in this study reported a 4-fold greater sense of fun when engaged in ROM exercises during VR distraction than without it. This is an important finding in that anticipatory anxiety and an increased pain experience can result from the performance of repeated, painful medical procedures, and may be attenuated with behavioral interventions. Although we did not assess it, one might speculate that the fun associated with VR distraction during painful PT may be a valuable incentive for patients to be more cooperative with, and more consistent in, their therapy, potentially enhancing rehabilitation success, as well as pain reduction. Together, these observations provide increasing evidence that VR distraction analgesia while controlling for individualized and varying pharmacologic analgesic dosing that necessarily occurs in the clinical setting. Our principal finding was that VR distraction, when added to standard analgesic care, resulted in statistically significant and/or clinically significant (defined as at least 33% or greater) reductions in subjective pain reports for 3 complementary dimensions of the pain experience (sensory, emotional, and cognitive pain). The magnitude and direction of the VR analgesic effect were consistent with those reported in previous pilot studies in the same burn PT setting.

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One interesting finding of our study is that patient assessments of the VR experience differed with age, with children and adolescents (≤18y) reporting a greater sense of realism of the virtual environment and a greater feeling of presence in that environment compared with adults (≥19y). Such age dependence of user impression of virtual environments has been previously reported, and may seem predictable, given the more regular exposure that children have to similar audiovisual experiences (eg, videogame entertainment). Relevant to the issue of pain relief, however, the age-dependent difference in VR experience we found did not translate into an age-dependent difference in VR analgesic effect. This observation suggests that under the conditions of the current study, the magnitude of VR presence may not correlate with the magnitude of analgesic effect. This relationship has been explored in experimental pain studies with VR distraction using manipulations of immersiveness designed to affect both presence and analgesic effect. Increasing immersiveness by changing VR helmet characteristics, sound exposure, and user interactivity results in both increased user presence and analgesic effect, whereas increasing immersiveness by changing helmet characteristics alone does not affect user presence, but does affect analgesia. This is an important topic for further study because it would be useful to determine the optimal VR hardware and software system configurations that produce maximal distraction analgesia at the lowest cost. For example, the cost of a maximally immersive VR distraction system (such as the one we used) is currently about $30,000. Consumer-level audiovisual distraction systems (eg, handheld videogames) cost significantly less, but appear to provide significantly inferior distraction analgesia. The cost-benefit balance of VR analgesia technology will become more clear as additional studies determine the potential reduction in hospital costs associated with VR analgesia (eg, shorter procedure times, more effective therapy procedures resulting from less pain), and hardware development and marketing trends lead to less expensive VR system components.

Study Limitations

This study had several limitations. First, in an effort to maximize the sample size, we combined data from 3, yet-to-be-completed studies. We described the rationale for this strategy above, but a single study protocol would be a more preferable study design. Second, the conditions of the standard care control group were based on the standard clinical care provided at our institution. It did not, however, provide any form of attentional control to adjust for potential bias of the subject or the therapist during the VR distraction condition. Nonetheless, objective neural correlates of VR analgesia have been reported using functional brain imaging, demonstrating reductions in pain-related brain activity during VR distraction (compared with no VR) in healthy volunteers experiencing thermal pain stimulation. Although our study population was significantly larger than that of any previously reported clinical trial of VR distraction analgesia, the limited numbers of female and nonwhite subjects do not completely exclude the possibility of a type II error in concluding that VR analgesic effect is independent of sex and ethnicity. Fourth, our outcome measures were limited to subjective pain ratings and assessments of the VR experience and did not include measures of functional therapeutic outcome (eg, maximal PROM) of significant clinical importance. Last, nausea assessments were only obtained in the standard (pharmacologic) analgesic care plus VR distraction condition, and therefore do not specifically reflect the incidence of simulator sickness associated with VR distraction alone. In fact, opioids—well known for their nauseating side effects—were used in the standard care regimen in the majority of the subjects, and may have been responsible for an unknown portion of the reported nausea.

CONCLUSIONS

Our results indicate that VR distraction is an effective adjunctive pharmacologic analgesic technique for burn-related rehabilitation activities. Compared with standard an-
algesic care alone, this intervention resulted in significant reductions in complementary subjective patient pain ratings and did not appear to be affected by patient age, sex, or ethnicity. Future investigations should explore its effects on pain reduction and potential enhancement of functional outcome in other painful rehabilitation settings.

Acknowledgments: We acknowledge Laura Jewett, BA, and Maryam Soltani, MEd, for their invaluable technical assistance with this study.

References


Suppliers

a. Hunter Hoffman, PhD, Human Interface Technology Lab, #352142, 215 Fluke Hall, University of Washington, Seattle, WA 98195.
b. Polhemus, 40 Hercules Dr, PO Box 560, Colchester, VT 05446.
c. NVIS Inc, 11495 Sunset Hills Rd, Ste 202, Reston, VA 20190.
d. Version 9; SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.

Objective: To identify barriers to return to work after burn injury as identified by the patient.

Design: A cohort study with telephone interview up to 1 year.

Setting: Hospital-based burn centers at 3 national sites.

Participants: Hospitalized patients (N=154) meeting the American Burn Association criteria for major burn injury, employed at least 20 hours a week at the time of injury, and with access to a telephone after discharge.

Intervention: Patients were contacted via telephone every 2 weeks up to 4 months, then monthly up to 1 year after discharge.

Main Outcome Measures: A return to work survey was used to identify barriers that prevented patients from returning to work. A graphic rating scale determined the impact of each barrier.

Results: By 1 year, 79.7% of patients returned to work. Physical and wound issues were barriers early after discharge. Although physical abilities continued to be a significant barrier up to 1 year, working conditions (temperature, humidity, safety) and psychosocial factors (nightmares, flashbacks, appearance concerns) became important issues in those with long-term disability.

Conclusions: The majority of patients return to work after a burn injury. Although physical and work conditions are important barriers, psychosocial issues need to be evaluated and treated to optimize return to work.

Key Words: Burns; Employment; Rehabilitation; Work. © 2007 by the American Congress of Rehabilitation Medicine

SEVERE BURN INJURIES often result in significant barriers to return to work that include contractures, amputations, weakness, and psychologic issues such as body image concerns, depression, and posttraumatic stress. The ultimate goal of a rehabilitation program for people who were employed before their burn injuries is to return them to work at their previous jobs. This is often a challenging task, and it may require a gradual reintegration into the workplace with modified work duties and close coordination with the employer. The vocational plan has to address the barriers to returning to work for people with burn injuries, but these barriers have not been systematically studied or identified from the patient’s perspective.

In a previous analysis of the multicenter data on patients with major burn injury as defined by the American Burn Association (ABA), 70% of adult patients were working outside of the home before their burn injuries. Unlike other severe traumatic injuries such as brain or spinal cord injuries, a large percentage of burn injuries occur at the workplace. Up to 30% of all major burn injuries among adults occurred at the workplace, and in the group that was employed before the burn injury 42% were injured at the workplace. Furthermore, people who were injured at work were more likely to have hand burns and to require hand surgery, factors that can have an impact on the ability to return to work.

Multiple variables influence a person’s ability to return to work after a burn injury. In a study using the Community Integration Questionnaire, the productivity score—reflecting work, school, and volunteer activities—was best predicted by a subject’s age, severity of burn injury, and level of preinjury job satisfaction. Brych et al reported that 66% of subjects with burn injuries had returned to work at 1 year and 90% at 2 years after injury. The average time off work was 17 weeks, and predictors of not returning to work included burn size, having an extremity burn, and psychiatric history. Similar findings were reported by Helm and Walker, who found that the mean time off work was 17 weeks in a sample of 65 patients. The severity of the burn injury was the most significant predictor of time to return to work. In a cross-sectional study from Sweden, Oyster-Aas et al found at an average follow-up time of 9 years postinjury that 83% of subjects with burn injuries were employed. Those not working reported worse outcomes on the Burn Specific Health Scale and reported significantly more problems with pain. Of those employed, 62% had the same job as before the injury, but 11% of them reported job difficulties. Although most were in a similar or better job than before the injury, 8% reported being in a worse or less skilled job because of burn-related factors. Tantulra et al also found that the severity of the burn injury and age correlated with return to work, but the presence of hand burns did not. Two studies have reported that an important predictor of working after a burn injury is the employment status at the time of injury. Fauerbach et al found that preburn substance abuse was associated with unemployment 4 months after the burn injury. In addition, trends for higher unemployment rates 12 months after discharge were noted among those with a preburn history.
of complex psychiatric comorbidity and alcohol use, anxiety, or mood disorder.

Electrical injuries often have complications such as amputations and neurologic injury, but return to work after an electrical injury has not been studied in detail. In a case series of patients with electrical burns, 91% of the injuries were reported to be work related, and of those who returned to work, the average time off work was 17.4 weeks. Only 23% of patients with electrical burns returned to the same work duties, 46% had to change work responsibilities, and 32% did not return to work at the average follow-up time of 5 years.11

Although studies have identified predictors of returning to work such as age and the severity of the burn injury, there is limited information regarding the barriers to returning to work after a significant burn injury. The aim of this study was to identify the specific barriers to returning to work resulting from the burn injury, as identified by the person with the burn injury and the changes in the perceived barriers over time.

**METHODS**

**Participants**

This study is a prospective study of 154 patients from 3 burn centers that participated in a federally funded, multisite data collection project (University of Washington, University of Texas Southwestern Medical Center, Johns Hopkins University). Patients were included if they met ABA criteria for major burn injury2 and if they were employed at least 20 hours a week at the time of the injury. Patients were excluded if they were not working at the time of the injury, did not have access to a telephone, or did not speak English (the University of Texas site was an exception, because Spanish-speaking patients were included at that site). All 3 institutions’ institutional review boards approved this study.

The mean total body surface area (TBSA) burn sustained by the patients ± standard deviation was 17.4%±13.7%, and the majority (57.5%) of our sample sustained burn injuries of less than 15% of TBSA. The mean length of hospitalization was 18.6±19.4 days, 80.4% of the patients were men, and 72% were white. The mean age was 37±12.3 years, and 34% of the patients were burned at work.

**Measures and Procedures**

Before hospital discharge, all patients who met study criteria were approached by a member of the research team to determine their interest in participating in the study. Patients who expressed interest gave consent for the study and completed the first part of a return-to-work (RTW) survey, which was developed specifically for this project. This survey is based on the Work Experience Survey (WES) developed by Roessler et al.12,13 The WES survey is a structured interview that identifies essential job functions in 6 categories: physical abilities, cognitive abilities, task-related abilities, social abilities, working conditions, and company policies; and it has been used to study vocational issues in people with disabilities.14,15 Each person completing the WES is asked to identify the essential job functions that are barriers to work, and these can be used to develop appropriate workplace accommodations. The RTW survey used in this study incorporated elements of the WES but was modified to include items pertinent to people with burn injuries such as wound issues. In addition, the WES list of essential job functions was modified to shorten the survey. For example, the WES includes 5 items regarding lifting of specific weight ranges, and this was consolidated in the RTW survey to 1 item asking about lifting as a barrier.

The RTW survey is a structured interview that has 3 sections. Section 1 is completed before hospital discharge and provides information concerning patients’ assessments of any preburn injury impairments, work environment, and satisfaction with the work or employer. It also asks if the employer or coworkers have contacted them while hospitalized. After discharge, patients were contacted by telephone to complete section 2 of the RTW survey every 2 weeks until 4 months postdischarge and then monthly up to 1 year postdischarge or until they returned to work, whichever came first. The survey was completed within a 7-day window of time before or after the scheduled 2-week follow-up or a 2-week window of time before and after the scheduled monthly follow-up. Section 2 asks patients to identify what they perceive as barriers to their returning to work by selecting from the 9 general categories (appendix 1). Patients were also asked to identify what they perceived as any specific barriers under each broad category (see appendix 1). To quantify the data, patients were asked to rate each general category on a 10-point graphic rating scale (GRS) in terms of how much of an impact each category had in preventing them from returning to work, ranging from 0 (no impact) to 10 (a lot of impact).

Once the patient had returned to work, he or she no longer was asked to complete section 2 but completed the exit survey, section 3, of the RTW evaluation via telephone interview. Section 3 of the survey was obtained within a month after returning to work. This section gathered information concerning job accommodations and difficulty in returning to work as well as satisfaction in returning to work. A manual outlining the use of this survey was developed for use by the 3 study sites. All institutions conducted the survey on 2 mock patients to ensure 80% interrater reliability.

**Data Analysis**

One-way analysis of variance methods were used to compare means of the GRS impact scores for each of the 9 major domains (see appendix 1). Means of the GRS scores were calculated using the latest valid assessment that each patient provided just before returning to work. Means for a single comparison group (the censored group), with which all others are compared, were derived from the assessments of patients who had not returned to work. The censored group includes subjects who had not returned to work at the time of their last follow-up and it is not known if they ever returned to work and those who completed the 1-year follow-up and had not returned to work. The use of the censored group implies that the analysis did not make assumptions regarding subjects in the censored group, who could have returned to work the day after their last follow-up or after the 1-year follow-up. This strategy provides 2 advantages. First, the samples at each time point for which means were computed are independent from each other and also independent of the censored group. Second, these comparisons allow evaluation of changes in barriers among groups of people with burn injuries based on elapsed time from discharge and provides insight into the durability of identified barriers over time. The goal was to determine if the barriers remained the same the longer people did not return to work. The Dunnett multiple-comparisons procedure was used to determine the statistical significance between each of the time periods and the single comparison (censored) group. P values less than .05 for simple pairwise comparisons were not deemed statistically significant unless the overall test of mean differences across all the assessment periods evaluated was significant at the .05 level of significance. This approach controls the overall experimental error rate for each comparison with the nominal .05 level of significance.
It was hypothesized that the severity of the burn injury as measured by TBSA burned and length of hospitalization would delay return to work and that employer contact during hospitalization would facilitate return to work. To evaluate this, logistic regressions were performed to evaluate the independent effects of these risk factors on the likelihood that subjects returned to work within 1 year postdischarge. In addition, Kaplan-Meier product-limit estimates and testing procedures were used to compare time-to-event (TTE) curves for these 3 factors. Both the log-rank tests, which assess median time to event, and Wilcoxon tests, which compare overall TTE curves, were calculated to assess statistical significance across the various risk strata for each risk factor.

Chi-square tests of significance were executed to compare the individual elements that influenced a particular composite score, each determined by the binary response yes or no. Similar to the previous strategy used for computing the means of the composite scores, we calculated percentages of times a characteristic was mentioned as a barrier to returning to work at each of the time periods and in the censored group. As before, depending on the number of assessment periods considered (t), each comparison was represented as a 2x(t) contingency table with t-independent samples, and thus the simple chi-square test was applicable.

Because of the large number of composite scores (n=9), the diversity of items within each composite score (range, 2–11 items; average, about 5 per composite score), and the total number of assessment periods (n=16) included in this study, not all of the results of all the possible statistical tests are presented in this study. Only significant and interesting ones are described. All data processing, calculations, and statistical tests were performed using SAS.29 Tests were deemed statistically significant if the computed significance levels were less than .05.

**RESULTS**

A total of 154 patients were entered into the study, for whom baseline data were collected. One patient with baseline data was excluded because this person did not provide any follow-up data and it was not known if this person ever returned to work. Although the maximum number of section 2 assessments for people who could range from 0 to 16, the actual number depended on when the person returned to work, and rarely did anyone complete all their possible evaluations. The number of assessments per person ranged from 0 (for 24 subjects) to 16 assessments (for 1 person), with a mean of 3.0 evaluations per patient (median, 1.5). A patient who returned to work before the first 2-week evaluation would not have answered any of the section 2 survey questions. If patients were not contacted at a specific time point, their data for that period were coded as missing. In this study, only 31 (20.3%) subjects did not return to work before the end of the 1-year follow-up period; alternatively, 79.7% returned to the workforce within 1 year postdischarge.

Most in the sample were working 40 to 50 hours a week, had been at their jobs an average of 8.3 years, and reported a job satisfaction rating of an 8.3 out of a 10-point scale (range, 1 [extremely unsatisfied] to 10 [very satisfied]). A total of 71% of patients reported that their employer contacted them to offer support during their hospitalization, and 81% reported that coworkers had called to offer support. Only 13% reported that they had any health concerns before the burn injury.

**Return to Work**

Table 1 reflects the number of people who had returned to work at each follow-up time, the cumulative number, the cumulative percentage, and the number censored (patients with no further follow-ups after this assessment for whom it is not known if they ever returned to work). Denominators were based on the total sample, including those who were not working at each follow-up and those whom we did not reach. By 2 weeks postdischarge, 12 (7.8%) patients had returned to work. The number of subjects returning to work at each follow-up period remained stable until about 12 weeks postdischarge, when 62.1% had returned to work. After 12 weeks, the number per week diminished to approximately 0.8 returning to work per week on average, and by 1 year postdischarge, 79.7% of the patients had returned to work.

**Barriers to Work (Section 2 of RTW Survey)**

At each section 2 follow-up, patients used a GRS (range, 0 [no impact] to 10 [a lot of impact]) to rate the impact that each
identified barrier had on their inability to return to work at that time (table 2). Shortly after discharge, “physical abilities” was identified as the most important barrier to returning to work until 10 months postdischarge, when “work conditions” became the most significant barrier. “Wound issues” was the second greatest barrier in the early follow-up time points but became less important at the mid to late time points. The pattern of the “social abilities” barrier over time also showed that it was not a significant barrier at the early follow-ups but became another important barrier around 10 months after discharge.

Statistical tests were performed among all 9 GRS composite mean scores, at the selected assessment times of 2 weeks, 6 weeks, and 10 weeks, to compare these means with the censored group means. These tests showed that only the cognitive abilities, social abilities, and working conditions categories were statistically significant (P<.05) when compared with the means of the censored group who responded to the 1-year survey. “Physical abilities” had the highest impact for both of the groups who had returned to work shortly after discharge and those not returning by 1 year. Cognitive abilities, social abilities, and working conditions did not have an impact early after discharge; however, these factors became highly significant barriers a year after discharge, as can be seen by the fact that their respective means at 1 year were significantly increased over the 2nd, 6th, and 10th week means. Although chi-square tests of each of the 9 major categories and all individual items within a category were performed, our analyses focused on the social abilities category, because of previous reports of the incidence of depression and posttraumatic stress symptoms after burn injuries.19-21 The social abilities category included evaluations of symptoms of both depression and posttraumatic stress disorder. The percentages of positive responses for all the specific reasons within this major category are provided in table 3. The reasons of “working alone” and “depressed mood” were the most common barriers identified in this category. All symptoms, with the exception of “supervising others” and being “afraid of workplace” rose steadily over

<table>
<thead>
<tr>
<th>Time After Discharge</th>
<th>Physical</th>
<th>Cognitive</th>
<th>Social Abilities</th>
<th>Task-Related Issues</th>
<th>Working Conditions</th>
<th>Wound Issues</th>
<th>Legal, Family, or Employer Reasons</th>
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NOTE. Values are means. Scoring range: 0 (no impact) to 10 (a lot of impact).

| Table 2: Average GRS Impact of the Identified Barriers to Return to Work |
|---------------------------|---------------------|-----------------|-----------------|------------------|
| Time After Discharge      | Physical            | Cognitive       | Social Abilities | Task-Related Issues |
| 2wk                       | 7.1                 | 0.9             | 2.1             | 4.7              |
| 4wk                       | 6.6                 | 0.7             | 2.5             | 4.8              |
| 6wk                       | 7.3                 | 0.8             | 2.3             | 4.9              |
| 8wk                       | 7.2                 | 1.8             | 3.2             | 5.1              |
| 10wk                      | 6.9                 | 1.3             | 3.5             | 5.8              |
| 12wk                      | 7.2                 | 1.8             | 2.7             | 5.9              |
| 14wk                      | 6.9                 | 2.7             | 4.3             | 5.8              |
| 16wk                      | 7.2                 | 2.7             | 4.5             | 6.1              |
| 5mo                       | 7.2                 | 2.6             | 4.3             | 6.0              |
| 6mo                       | 7.1                 | 2.5             | 4.4             | 4.5              |
| 7mo                       | 6.7                 | 2.5             | 4.1             | 5.6              |
| 8mo                       | 6.5                 | 3.2             | 4.0             | 5.8              |
| 9mo                       | 6.6                 | 4.0             | 4.8             | 5.4              |
| 10mo                      | 6.4                 | 2.4             | 6.3             | 5.4              |
| 11mo                      | 6.4                 | 3.2             | 5.6             | 4.2              |
| 12mo                      | 7.7                 | 2.7             | 6.2             | 4.7              |

NOTE. Values are means. Scoring range: 0 (no impact) to 10 (a lot of impact).

<table>
<thead>
<tr>
<th>Table 3: Percentage of Subjects Who Identified Return-to-Work Barriers in the Social Abilities Category by Assessment Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time After Discharge (n)</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>2wk (82)</td>
</tr>
<tr>
<td>4wk (73)</td>
</tr>
<tr>
<td>6wk (58)</td>
</tr>
<tr>
<td>8wk (47)</td>
</tr>
<tr>
<td>10wk (35)</td>
</tr>
<tr>
<td>12wk (23)</td>
</tr>
<tr>
<td>14wk (22)</td>
</tr>
<tr>
<td>16wk (22)</td>
</tr>
<tr>
<td>5mo (16)</td>
</tr>
<tr>
<td>6mo (17)</td>
</tr>
<tr>
<td>7mo (11)</td>
</tr>
<tr>
<td>8mo (10)</td>
</tr>
<tr>
<td>9mo (13)</td>
</tr>
<tr>
<td>10mo (11)</td>
</tr>
<tr>
<td>11mo (9)</td>
</tr>
<tr>
<td>12mo (9)</td>
</tr>
</tbody>
</table>

NOTE. Values are percentages.
time. Chi-square tests of all individual items within the social abilities category were performed, and comparisons of the 2nd, 6th, and 10th weeks with the censored group found statistically significant differences for all the specific elements that make up the social abilities category.

Post–Return to Work (Section 3 of RTW Survey)

Once patients had returned to work, they completed section 3 of the RTW survey, which included 2 questions on a scale of 0 to 10. The first rated how difficult it was to return to work, ranging from 0 (not difficult at all) to 10 (very difficult). The mean rating was 4.2±3.0. The second question asked how satisfied they were to be back at work, with 1 being ”not satisfied” and 10 being ”very satisfied.” The mean rating was 8.0±2.8. Of those returning to work, 94% returned to the same employer and 67% reported that they received special accommodations, including limited work hours (38%), limited days per week (14%), and light duty (38%).

Return-to-Work Risk Factors

Logistic regression models were evaluated to assess other contributors to returning or not returning to work within 1 year. The risk factors of employee concern, hospital length of stay, and TBSA were evaluated for their independent contributions to delayed return to work. None of these factors played a significant role in delaying return to work after discharge, as shown by significance tests results of .48, .32, and .25, respectively. To assess whether these factors influenced the speed at which subjects returned to work, several TTE analyses were performed. Evaluations of Kaplan-Meier curves among the various strata of these risk factors showed no effect of employer concern (log-rank, .49; Wilcoxon, .55) or TBSA (log-rank, .35; Wilcoxon, .20); however, length of stay (log-rank, .05; Wilcoxon, .051) tended toward having a significant impact in delaying return to work.

DISCUSSION

For people who were employed at the time of a severe burn injury, return to work is often the most important and challenging treatment goal. As seen in a previous study, most of the patients in this study were successful in returning to work by 1 year after discharge, but over 20% of the patients did not return to work because of burn-related disability. The patients in this study had stable work situations, with an average pre-injury time at their jobs of 8.3 years and good job satisfaction. Subjects also reported that 71% of them were contacted by their employers during their hospitalization, and 81% were contacted by coworkers. Franche et al report that there is evidence that early contact by the employer reduces the duration of disability, but contact by the employer during hospitalization was not found to be a significant predictor of time off work in this study. This may be due to the large number of subjects (71%) who had some contact by their employers and the fact that we did not characterize the nature or amount of contact between injured workers and their employers. It is possible that in-depth or multiple employer contacts during the acute hospitalization would correlate to a work situation more likely to make accommodations and facilitate a return to work.

Return to work after an injury involves multiple stakeholders, including the employee and his/her family, the employer, the health care system, and the insurance and workman’s compensation systems. As such, multiple complex and possibly competing factors can influence the potential for return to work after an injury. Previous studies have generally not focused on the perspective of the injured worker in the analysis of return-to-work outcomes. This study focused on the perception of patients with burn injuries and their perceived barriers to returning to work.

To interpret the impact of different categories on return to work (see tables 2, 3), the changes in the subject sample over time must be recognized. When a subject returned to work, he/she no longer participated in the ongoing section 2 follow-up phone calls. Therefore, the study started with 154 subjects, and almost 70% had a relatively short-term disability and had returned to work by 4 months. The last several follow-up calls were completed on less than 40 subjects who had not returned to work by that time, a sample with long-term disability due to their burn injuries. It was expected that the physical and wound-related barriers would be important factors early after discharge from the hospital, and the treatment of physical and wound-related problems is the initial primary focus of a burn care and rehabilitation team after a significant burn injury. Many people are unable to return to work with wound care issues requiring dressing changes and risk of wound contamination at the workplace. Physical barriers such as decreased range of motion or decreased hand function may also prevent a person from returning to work and are a priority of the rehabilitation treatment plan. Physical barriers continued to be a significant problem throughout the study, but as expected, wound issues decreased over time.

An injured worker has little control over work task–related issues and working conditions, but patients identified these as important factors in the inability to return to work. In fact, working conditions was the most important barrier in those who had not returned to work at 12 months. These barriers can be minimized through accommodations by the employer, and 67% of the subjects in this study who had returned to work received workplace accommodations. There is evidence that the availability of workplace accommodations does decrease the duration of disability. An employee can negotiate the necessary workplace accommodations in discussions with the health care provider and the employer, and there is evidence that the duration of disability is reduced when a health care provider contacts the workplace. This contact can be made by any member of the health care team, but it is ideally made by a vocational rehabilitation counselor who has the training and expertise to evaluate each patient’s impairment and the demands of the workplace and who can negotiate suitable accommodations. This intervention will facilitate a successful return to work.

There are also multiple psychosocial factors that prevent a successful return to work. There is increased recognition of these factors as health care moves away from a traditional biomedical model of disability toward a biopsychosocial model. This model is proposed by the World Health Organization in the International Classification of Functioning, Disability and Health (ICF) and recognizes the complex relationship between a person’s body function and structure, environmental factors, personal factors, and the impact on the ability to complete activities and participate in daily roles such as vocational pursuits. The ICF model has been used to examine the consequences of burn injuries. The psychosocial risk factors for prolonged disability can exist within a person (depression, anxiety/fear, lack of confidence) but can also exist within the workplace (job stress, coworker support). In this study these psychosocial barriers to work were measured under the general category of social abilities. In the early follow-up periods, the social abilities category had a low impact rating of approximately 2.0, and this increased to approximately 6.0 at the last follow-up. The percentages of patients endorsing items in the social abilities category signifi-
significantly increased over time. This indicates that in those people with prolonged disability, psychosocial factors were a very important factor preventing them from returning to work. Further review of the data shows very high rates of psychologic issues such as nightmares or flashbacks, concern over appearance, and depressed mood preventing return to work. Other studies have shown the role of depression in predicting return to work. Long-term psychologic issues need to be evaluated and treated after burn injuries, but in this study we did not collect information regarding the accessibility of psychologic services or if subjects received counseling or medications.

**Study Limitations**

The study has several limitations. The sample, on average, consisted of subjects with relatively small burn injuries (vs people with >50% of TBSA burn injuries), which may not present long-term physical barriers to work. The sample included only those who were employed at the time of the injury and did not address the population of those who were unemployed and have a very difficult time finding employment at a new job after a burn injury. In addition, we did not collect information on work retention or the ability to keep a job over time. People may receive workplace accommodations only for a limited period of time and have difficulty progressing back to full duty and keeping their jobs over the long term. The data collected in the study are limited to each patient’s perception of the barriers to returning to work. Although this was the intent of the study, there is no objective measure to verify the significance of the perceived barrier. The final limitation is the limited number of subjects included at the later follow-up periods, due to a majority of subjects having returned to work before 4 to 6 months after discharge.

**CONCLUSIONS**

This study shows the barriers to return to work over time as perceived by people with burn injuries. Although there is a group of people who return to work within a few months of hospital discharge and report problems primarily with physical and wound issues, over 30% of subjects with burn injuries have longer-term disabilities. In these subjects, vocational rehabilitation counseling is recommended to assist with the assessment of the workplace, identification of appropriate workplace accommodations, and facilitation of a successful return to work. People with long-term disability also report increasing problems with psychosocial issues in addition to physical and work issues. These people can benefit from psychologic intervention as part of the overall treatment plan that includes a return-to-work goal. If these people are identified early in the recovery period and a psychologic and vocational treatment program is started, they may be able to return to work sooner.

**APPENDIX 1: CATEGORIES OF BARRIERS TO RETURN TO WORK IN SECTION 2 OF THE RTW SURVEY**

<table>
<thead>
<tr>
<th>Physical Abilities</th>
<th>Working Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working 8 hours in a day</td>
<td>Temperature</td>
</tr>
<tr>
<td>Standing</td>
<td>Humidity</td>
</tr>
<tr>
<td>Kneeling</td>
<td>Workplace safety</td>
</tr>
<tr>
<td>Climbing</td>
<td>Odors/fumes</td>
</tr>
<tr>
<td>Pulling/pushing</td>
<td>Working outdoors</td>
</tr>
<tr>
<td>Raising arms above shoulders</td>
<td>Going back to where I was hurt</td>
</tr>
<tr>
<td>Using hands</td>
<td></td>
</tr>
<tr>
<td>Using legs</td>
<td></td>
</tr>
<tr>
<td>Lifting</td>
<td></td>
</tr>
<tr>
<td>Prolonged sitting</td>
<td></td>
</tr>
<tr>
<td>Handling</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cognitive Abilities</th>
<th>Wound Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>Splints</td>
</tr>
<tr>
<td>Judgment</td>
<td>Pressure garments</td>
</tr>
<tr>
<td>Problem solving</td>
<td>Dressing changes</td>
</tr>
<tr>
<td>Organizing</td>
<td>Open skin wounds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Abilities</th>
<th>Legal/Family/Employer Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working alone</td>
<td>Lawyer advised against working</td>
</tr>
<tr>
<td>Working with others</td>
<td>Family advised against working</td>
</tr>
<tr>
<td>Supervising others</td>
<td>Employer advised against working</td>
</tr>
<tr>
<td>Afraid to leave home</td>
<td>Job no longer exists</td>
</tr>
<tr>
<td>Afraid of the workplace</td>
<td></td>
</tr>
<tr>
<td>Nightmares or flashbacks</td>
<td>Transportation</td>
</tr>
<tr>
<td>Concern about my appearance</td>
<td>I cannot drive</td>
</tr>
<tr>
<td>Depressed mood</td>
<td>My family cannot take me to work</td>
</tr>
<tr>
<td>Fear</td>
<td>There is no bus</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task-Related Issues</th>
<th>Medical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work pace</td>
<td>Doctor has not released me</td>
</tr>
<tr>
<td>Stress/deadlines</td>
<td>I have other, new medical problems</td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td></td>
</tr>
<tr>
<td>Using computer</td>
<td></td>
</tr>
<tr>
<td>Using telephone</td>
<td></td>
</tr>
</tbody>
</table>
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Supplier

a. Version 9.1; SAS Institute, 100 SAS Campus Dr, Cary, NC 27513.
Physical and Psychologic Rehabilitation Outcomes for Young Adults Burned as Children

Christine P. Baker, EdD, PT, William J. Russell, MA, Walter Meyer III, MD, Patricia Blakeney, PhD


Objective: To report physical and psychologic outcomes for young adult survivors of pediatric burns.

Design: Prospective, correlational study.

Setting: Acute and rehabilitation pediatric burn care facility.

Participants: Eighty-three young adult survivors of pediatric burns, who were 18 to 28 years of age, with total body surface area (TBSA) burns of 30% or greater, and were at least 2 years postburn.

Interventions: Not applicable.

Main Outcome Measures: Physical outcomes were assessed by muscle strength tests, grip and pinch measurements, mobility levels, and self-care (activities of daily living) skills. Psychologic outcomes included behavioral problems, personality disorder, and incidence of psychiatric illness. An individually administered Structured Clinical Interview for Diagnosis, based on the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, for psychiatric diagnosis, was used to assess mental health, and behavioral problems were assessed with the Young Adult Self-Report. Participants reported educational achievement, employment status, state of transition from family of origin (home) to independent living, and pair bonding. The Short-Form 36-Item Health Survey and the Quality of Life Questionnaire were used to assess each participant’s self-reported general health and quality of life.

Results: The majority of subjects had physical and psychologic outcomes that were within the normal range when compared with age-mates who had not experienced burns. The areas that were most likely to be impaired involved peripheral strength (wrist and grip). These deficits affected some self-care skills and correlated with TBSA. Standardized diagnostic interviews showed that greater than 50% of subjects qualified for a psychiatric diagnosis, with anxiety disorders as the most common. Interviews showed that greater than 50% of subjects qualified for a psychiatric diagnosis, with anxiety disorders as the most common. From family of origin (home) to independent living, and pair bonding. The Short-Form 36-Item Health Survey and the Quality of Life Questionnaire were used to assess each participant’s self-reported general health and quality of life.

Conclusions: Most of the people in this sample were functioning physically and psychosocially within normal limits as they reached adulthood. Although they appeared to function well as measured by standardized assessments, there were indications of private suffering that suggested they may not be functioning at an optimal level. The findings suggest that rehabilitation professionals could improve outcomes by including programs to develop overall muscle strength in severely burned children and by addressing concerns related to anxiety and other symptoms of psychologic distress.

Key Words: Burns; Child psychiatry; Diagnosis; Outcomes research; Quality of life; Rehabilitation. © 2007 by the American Congress of Rehabilitation Medicine

THE QUESTION OF rehabilitation outcomes for pediatric burn survivors has become more prominent over the past 2 decades as medical science and surgical techniques have advanced so that most burned children survive. Each year 40,000 to 50,000 people are admitted to hospitals for severe burn injuries in the United States; approximately 25% of these are under 18 years of age.1-12 Whereas 40 years ago, only half of the children with total body surface area (TBSA) burns of 50% could be expected to survive, now half of those with TBSA burns of 85% can be expected to survive.1 In fact, those children who reach a burn center with burns of greater than 70% of TBSA now routinely survive.1 Of note, 1 burn center reported that in 2006, there was a 50% survival rate of children ages 0 to 14 years with burns of 99% of TBSA.3

In contrast to advances in acute care, relatively little is known about the long-term outcomes of children with burn injuries and even less is known about their functioning when they enter adulthood. Most outcomes assessments of pediatric burn survivors focus on the immediate burn period through the first 2 years postburn and use standardized assessment tools designed for general populations rather than tools to identify specific difficulties of burned children. In these reports, the majority of young survivors seem to have reasonably good outcomes; only about 30% have significant psychosocial problems,10-12 and even those with massive injuries and amputations are usually reported to achieve appropriate physical independence.10-12 There are no true longitudinal studies that involve more than 1 time-point of evaluation for pediatric burn survivors. Although the study by Sheridan et al10 included young adults (mean age, 24y), only 2 published studies13,14 have evaluated aspects of long-term adjustment specifically at the time when survivors of childhood burns are making the transition from dependent adolescents to independent adults. In 1988, investigators at the University of Texas Medical Branch and Shriners Hospital for Children, Shriner’s Burns Hospital in Galveston, TX, examined 38 young adults who had experienced a burn covering at least 40% of TBSA. These investigators found that most subjects were in school or employed and were within normative limits on measures of psychologic adjustment. Those who had significant psychologic disturbance were different from their well-adjusted peers in their perceptions of their family cohesiveness and independence.13 A de-
were assessed in like manner. In addition, living arrangement and financial dependence tails of this relationship were explored in an open-ended inter-
ported that they had established a long-term partner. The de-
either worked or attended school. Twenty-seven percent re-
college, and 5% completed college. Seventy-seven percent 
completed, and the following data were obtained: 28% high 
school dropouts, 33% high school graduation only, 34% some 
completed, and the following data were obtained: 28% high 
school dropouts, 33% high school graduation only, 34% some 

Participants

This study was part of a comprehensive investigation con-
ducted at Shriners Hospital for Children, Shriners Burns Hos-
pital in Galveston, TX, and was supported by the National 
stitute-generated instrument corre-
lated with FIM scores at .92 or higher. Spearman rank corre-
lation coefficients for the combined sections of this instrument 
and the FIM averaged .96. No reliability data are available.

Instruments

Physical assessment instruments. The physical assess-
ment results were reflected by a variety of measures. Muscle 
strength was assessed using standard and widely accepted 
strength testing procedures by Kendall et al.12 A Jamar hand 
dynamometer1 assessed hand grip strength, and a B&L pinch 
gauge1 was also used. Hand grip and pinch strengths were 
associated with standard procedures for subject position 
and instructions, and the greatest of 3 trials was reported for 
each grip and pinch strength measure. Mobility evaluation examined 
each subject’s ability to assume various positions, such as 
side-to-side rolling, sitting, quadraped, kneeling, and standing. 
Stability was assessed by requiring subjects to hold positions 
against an externally applied force. Ratings were I (indepen-
dent) or A (requires assistance); these were then transcribed to 
numeric ratings for the data analysis. Each participant demon-
strated or reported his or her ability to perform activities 
of daily living (ADLs). ADLs were assessed with a self-report 
form developed at this facility (appendix 1). The instrument 
examines areas of mobility, hygiene, dressing, feeding, and 
home management. Each item was rated as 1 (independent), 2 
(independent but not performed normally), 3 (required equip-
ment), 4 (required supervision), 5 (required assistance), or 6 
(unable to perform). When appropriate, subjects demonstrated 
their abilities to perform the activity. An unpublished study 
(C.P. Baker, A. Hantz, L. Hillman, M. Shepherd, unpublished 
data, Feb 2003) examined the validity of this instrument, com-
paring the results with those of the motor section of the FIM 
instrument. Scores on the facility-generated instrument corre-
lated with FIM scores at .92 or higher. Spearman rank corre-
lation coefficients for the combined sections of this instrument 
and the FIM averaged .96. No reliability data are available.

Psychologic assessment instruments. A battery of psycho-
logic assessments was administered to each participant. Behav-
ioral problems were assessed with the Young Adult Self-
Report (YASR) for ages 18 to 30 years by Achenbach.25 The 
YASR contains a 119-item list of problem behaviors. Each 
behavioral item is rated as 0 for not true, 1 for somewhat or 
sometimes true, and 2 for very true or often true. The report 
can be interpreted by grouping the problem items into externaliz-
ing, internalizing, and total problems and/or by viewing the 
syndrome subscales—that is, anxious or depressed, withdrawn, 
somatic complaints, thought problems, attention problems, in-
trusive thoughts, aggressive behavior, and delinquent behavior. 
In addition to the problem scores, the YASR contains items 
about friends, education, job, family, spouse or other, illnesses 
or disability, concerns or worries, and the best things the people 
perceive about themselves; these items are scored to yield 
adaptive functioning subscales. Psychometric information for 
the YASR has been reported in the manual for the YASR and 
the Young Adult Behavior Checklist.25 Achenbach25 reports 
that test-retest reliability across the problem scales yielded a 
mean r of .84. In a matched sample of referred (for treatment 
of a clinical problem) and nonreferred subjects, the Total 
Problems Scale was highly predictive of referred subjects. 
When T scores were above 64 (clinical range for the instru-
ment), the probability that a referred subject was being identi-
fied ranged between .74 and .79 for men and .79 and .82 for 
women.25

Individually administered structured diagnostic interviews (Structured Clinical Interview for Diagnosis [SCID]) assessed mental health.26 This fully structured, clinical interview allows 
operationally defined, consistent, and accurate Axis I psychi-
atriac diagnoses according to the Diagnostic and Statistical 
Manual of Mental Disorders, 4th Edition, the official manual of
the American Psychiatric Association. Health-related quality of life (QOL) was measured by the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36). The SF-36 is designed for those 14 years of age and older and consists of 8 scales, including physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health. Two summary scores, physical health and mental health, are derived from the 8 scales. The SF-36 is age-normed to the general population and has excellent psychometric properties for both the general population and those with specific medical conditions. High internal consistency (Cronbach α range, .65–.97) and excellent test-retest stability (intraclass correlation coefficient range, .73–.97) have been reported. Many studies have investigated the relationships found between the SF-36 and other accepted health measures; correlations have ranged from .42 to .78. Further evidence of construct validity is reported by Brazier et al. Although used in a study of patients with burn injuries, the instrument’s specific reliability coefficients and validity have not been reported for this population.

The Quality of Life Questionnaire (QLQ) by Evans and Cope was used to assess long-term psychosocial adjustment. It is a multidimensional tool that examines various aspects of daily living with the assumption that certain behaviors are indicative of adaptive psychosocial functioning. It includes 192 true-false questions categorized into 5 major domains and 15 subdomains. The 5 major domains are general well-being, interpersonal relations, occupational activity, leisure activity, and recreational activity. The subdomains include material well-being, physical well-being, personal growth, marital relations, parent-child relations, extended family relations, extramarital relations (social support), altruistic behavior, political behavior, job characteristics, occupational relations, job satisfiers, creative/aesthetic behavior, sports activity, and vacation behavior. The QLQ has well-established psychometric properties, including construct validity. For example, internal consistency is reported as stable, with reliability coefficients ranging from .61 to .98, and test-retest reliability coefficients of .77 to .89.

Procedure

Participants were contacted by mail or telephone and invited to travel to the Shriners Burns Hospital in Galveston, TX to be assessed for psychosocial and physical well-being and difficulties. Data collection occurred between spring 2000 and fall 2002. A university institutional review board approved the study, participation in the study was voluntary, and written consent was obtained before participation. All potential subjects were contacted by telephone, and notes were taken to document reasons for nonparticipation and burn demographics. People who refused to participate in the study did not have significantly different demographics related to age, sex, ethnicity, or TBSA, but the nonparticipants were younger at the time of burn than those who participated.

In the Shriners Hospital system, all patients are routinely followed up for health needs and are provided with needed medical intervention until they reach the age of 21 years. The typical physical rehabilitation interventions for subjects in our study included positioning, splinting, scar massage and management to affected areas, pressure dressings and compression garments, active and passive exercise, facilitation of normal physical development, strength and endurance training, ambulation, participation in functional and self-care activities, and caregiver education. During participants’ inpatient and outpatient care, a coordinated team approach was used and included physicians, nursing person-
physically challenging was “walking on an unlevel surface”; 6% of subjects reported difficulty with this. No significant correlations were found between mean mobility and TBSA or mean stability and TBSA.  

**ADL skills.** Twenty-six self-care skills were assessed by demonstration or responses to questions. A majority (83%) of the young adults were able to address their own self-care needs without any modifications or assistive devices. Ninety-nine percent of subjects reported being independent in the areas of hygiene (toileting, bathing) and home management skills (ie, making a sandwich, opening a soda can, using a telephone). In dressing activities (eg, putting on pants), 98% of the subjects were independent. Feeding skills were the most varied of those examined; 88% were independent. Generally, people with more TBSA burned were more likely to have limitations in self-care abilities. This finding was significant for mobility ($r = -0.298, P = .006$) and dressing ($r = -0.251, P = .022$). However, these relationships, although statistically significant, represent fair or no clinical importance.  

**Relationships Between Physical and Psychologic Measures**  

No significant relationships were found between mobility and stability scores and the YASR problem subdomains; $P$ values ranged from .059 to .999, with the highest $r$ value of −0.218 found with the delinquent behaviors subscale. Few significant correlations were found with strength scores and the YASR problem subdomains. The only significant correlation between strength and YASR was found in mean shoulder strength and aggression subscale ($r = -0.228, P = .048$). Hand grip strength correlated significantly with the internalizing scale ($r = -0.308, P = .008$), anxious-dependent scale ($r = -0.294, P = .012$), and withdrawn scale ($r = -0.276, P = .018$); tip-to-tip pinch strength correlated significantly with the internalizing scale ($r = -0.245, P = .036$) and withdrawn scale ($r = -0.238, P = .043$). These correlations indicate a relationship between poor hand function and increased behavioral problems. Feeding was the only ADL area to have a significant relationship to any areas of the YASR; both total problems ($r = 0.267, P = .02$) and the attention scale ($r = -0.227, P = .049$) had significant correlations.  

The SCID results are reported in detail elsewhere. They showed that 45.5% received 1 or more current Axis I psychiatric diagnoses; anxiety disorders occurred with the highest prevalence (31%). Lifetime mental health diagnoses were more common; 59.4% had 1 or more lifetime Axis I diagnoses. Again, the anxiety disorders had a high prevalence (38%), but in this time frame affective disorders were also very common (44.4%). The prevalence of current and lifetime psychiatric diagnoses are twice the national prevalence. The presence of any current Axis I diagnosis, any current affect diagnosis and any current anxiety diagnosis were compared with the mobility, stability, strength, and ADL scores. None of the physical measures had significant relationships with the current SCID findings. The strongest, yet still nonsignificant, relationship was between physical stability and any current affective disorder with an $r$ value of .175 ($P = .12$).  

On the SF-36, mean values for the survivors on the physical component scale (PCS) and mental component scale (MCS) were 50.30 for men and 50.11 for women, similar to published norms (50.00 for each scale) for the U.S. population. The results suggest that these young adults perceive the impact of health on their lives in ways that are similar to those of the general population. Overall muscle strength correlated significantly to SF-36 PCS score ($r = 0.438, P < .001$). All hand and grip strength values correlated significantly with the physical functioning subscale of the SF-36 ($r$ range, .24–.31) but not with the overall PCS. However, handgrip and key (lateral) pinch strength correlated significantly with the MCS ($r = 0.289, P = .017$; $r = 0.309, P = .01$, respectively). Mobility ($r = -0.419, P < .001$) and stability ($r = -0.464, P < .001$) correlated with the SF-36 PCS values. None of the ADL scores correlated with PCS or MCS scores.  

The QLQ showed that burn survivors as a group rated their overall QOL (mean, 103.4 ± 22.3) significantly lower ($P < .001$) than the normative reference group reported by Evans and Cope34 (113.2 ± 20.4). None of the physical measures had significant relationships with the QLQ total score; the strongest, yet still nonsignificant, relationship was between the total QLQ and physical stability ($r = -0.200, P = .081$).  

**DISCUSSION**  

A large majority (93%) of our subjects with significant burns performed well physically. There were a few notable differences in overall strength and handgrip. Sixty-five percent of our subjects had normal muscle strength in all areas of the body, with another 19% having “good” strength as their lowest obtained strength value. Only

## Table 1: Average Strength Measurement Reported by Sex and TBSA

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Men (n=49)</th>
<th>Women (n=31)</th>
<th>&lt;50% TBSA (n=47)</th>
<th>&gt;50% TBSA (n=33)</th>
<th>All Subjects (n=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handgrip</td>
<td>473.29 (106.4)</td>
<td>236.56 (53.18)</td>
<td>396.34 (89.10)</td>
<td>361.53 (81.05)</td>
<td>381.57 (85.78)</td>
</tr>
<tr>
<td>Lateral (key)</td>
<td>100.98 (22.70)</td>
<td>69.39 (15.60)</td>
<td>90.61 (20.37)</td>
<td>86.47 (19.44)</td>
<td>88.88 (19.98)</td>
</tr>
<tr>
<td>Tip-to-tip</td>
<td>76.51 (17.20)</td>
<td>54.89 (12.34)</td>
<td>70.02 (15.74)</td>
<td>65.75 (14.76)</td>
<td>68.24 (15.34)</td>
</tr>
<tr>
<td>Tripod</td>
<td>96.55 (21.48)</td>
<td>72.11 (16.21)</td>
<td>91.68 (20.61)</td>
<td>79.53 (17.88)</td>
<td>86.56 (19.46)</td>
</tr>
</tbody>
</table>

### Table 2: Mean Hand Grip and Pinch Strength Values According to Mathiowetz et al44 and Jansen et al45 (italics)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Hand Grip</th>
<th>Key Grip</th>
<th>Tip-to-Tip</th>
<th>Tripod (palmar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men right</td>
<td>538.24 (121.00)</td>
<td>115.65/112.99 (26.00/25.40)</td>
<td>80.07/69.57 (18.00/15.64)</td>
<td>118.32/88.74 (26.60/19.95)</td>
</tr>
<tr>
<td>Men left</td>
<td>464.84 (104.50)</td>
<td>110.32/105.07 (24.80/23.62)</td>
<td>5.62/66.28 (17.00/14.30)</td>
<td>911.32/85.76 (25.70/19.28)</td>
</tr>
<tr>
<td>Women right</td>
<td>313.16 (70.40)</td>
<td>78.29/78.33 (17.60/17.61)</td>
<td>49.38/48.39 (11.10/10.86)</td>
<td>76.51/70.59 (17.20/15.87)</td>
</tr>
<tr>
<td>Women left</td>
<td>271.34 (61.00)</td>
<td>72.06/73.04 (16.20/16.42)</td>
<td>46.71/46.22 (10.50/10.39)</td>
<td>72.51/65.39 (16.30/14.70)</td>
</tr>
</tbody>
</table>

NOTE. Values are newtons (pounds).
35% of our subjects had any long-term strength deficits in any area of the body. Distal areas of the body (wrists, toes) were more likely to have impaired strength. It may be that these areas of the body were more likely to have surgical intervention, muscle loss, nerve damage, or partial or complete amputations, which could have affected the strength in these areas and the surrounding joints. For example, a person might have experienced an amputation of a finger or distal part of finger; this would not impair the ability to grasp the hand dynamometer but would result in decreased grip strength because not all fingers were able to exert force.

Our findings are somewhat surprising, because published literature suggests that people with burns often have marked muscle weakness in spite of standard occupational and physical therapy rehabilitation programs. Prolonged hospitalization may account for the loss of muscle mass and diminished cardiovascular endurance. The child who has been burned tends to move rigidly and slowly, which can result in limited activity and impaired strength. Children with larger burns may tire easily and may require strengthening and cardiovascular exercises appropriate to the age of the child, the specific area burned, and the strengthening and cardiovascular training devices available.

There was a sizable difference between postural mobility and stability (93% had normal postural mobility, but only 50% had postural stability rated as normal when assessed). We postulate that this is related to the diminished toe strength in 20% of the subjects; lack of a stable base would impair standing balance and the ability to walk on uneven surfaces. People flex their toes to grasp the ground or their shoes to gain stability during stance and gait. Further, toe muscle weakness decreases a person’s ability to invert and evert the foot and ankles, influencing the ability to adjust to perturbations. This relationship is speculative from the findings in this study and warrants future investigation.

Not surprisingly, when compared with age-mates who had not experienced burn injury, our subjects had lower grip and pinch strength values, as shown in tables 1 and 2. The findings by Mathiowetz et al for fifty-five 20- to 24-year-olds are not experienced burn injury, our subjects had lower grip and pinch strength values, and those for subjects aged 20 to 39 years (n = 11005) exceeded those reported by either Mathiowetz or Jansen. Our findings are somewhat surprising, because published literature suggests that people with burns often have marked muscle weakness in spite of standard occupational and physical therapy rehabilitation programs. Prolonged hospitalization may account for the loss of muscle mass and diminished cardiovascular endurance. The child who has been burned tends to move rigidly and slowly, which can result in limited activity and impaired strength. Children with larger burns may tire easily and may require strengthening and cardiovascular exercises appropriate to the age of the child, the specific area burned, and the strengthening and cardiovascular training devices available.

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These results suggest that a vast majority of children experiencing moderate to severe burns will be able to address their own self-care and mobility needs as young adults. Intensive exercise programs recently described in the literature might have resulted in a higher percentage of our subjects achieving normal muscle strength. However, the high rate of anxieties and diminished QOL reported indicate a degree of distress that we must address, and the surrounding joints. For example, a person might have experienced an amputation of a finger or distal part of finger; this would not impair the ability to grasp the hand dynamometer but would result in decreased grip strength because not all fingers were able to exert force.

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and interventions to address the psychosocial needs are just beginning to be tested. For the burn survivors in this study, the greatest apparent need during this transition is for psychosocial assistance. None of the young adults in this study, however, were receiving professional help for their difficulties. Most burn survivors who suffer psychologic symptoms of distress after discharge from a burn center and who desire treatment must rely on mental health professionals in the community. However, it may be difficult for them to find helpful resources, because such treatment is expensive and often not affordable by the patient, at least in the United States, without insurance or other financial assistance. Future research is warranted to determine what continued resources are needed to assist young survivors during this transition to optimally function as adults achieving to their greatest potentials.

**Acknowledgments:** We thank the Departments of Rehabilitation Services and Medical Records at Shriners Hospital for Children, Shriners Burns Hospital, Galveston, TX, for their collaboration and advice for this article. We also thank Mary Ellen Spellman, PT, Jennifer Ellison, PhD, PT, and Caroline Jansen, PhD, PT for their assistance with data collection.

**APPENDIX 1: ACTIVITIES OF DAILY LIVING EVALUATION**

<table>
<thead>
<tr>
<th>✓ Independent</th>
<th>D Dependent on (e) equipment, (s) supervision, (a) assistance</th>
<th>X Not able to perform</th>
<th>R Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOBILITY</strong></td>
<td><strong>HYGIENE</strong></td>
<td><strong>DRESSING</strong></td>
<td></td>
</tr>
<tr>
<td>Open door handles (all types)</td>
<td>Toileting</td>
<td>Puts on pants</td>
<td></td>
</tr>
<tr>
<td>_____ 1 hand</td>
<td>_____ Zip</td>
<td>_____ Button</td>
<td></td>
</tr>
<tr>
<td>Ambulates Independently</td>
<td>Bathing</td>
<td>Puts on shirt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>_____ Zip</td>
<td>_____ Button</td>
<td></td>
</tr>
<tr>
<td>In/Out Chair</td>
<td>Combs Hair</td>
<td>Puts on shoes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>_____ Zip</td>
<td>_____ Button</td>
<td></td>
</tr>
</tbody>
</table>

**FEEDING**

| Eats with spoon/fork | _____ Fist | _____ Pinch |
| Drinks from cup | _____ 1 hand | _____ 2 hands |
| Cuts with fork/knife |

**OTHER**

| Makes sandwich (R) | Uses telephone |
| Cooks on stove (R) | Clean room (R) |
| Open soda can | Make bed (R) |
| Open jar | Sweep floor (R) |
| What have they cooked? | Drive Car (R) |
| _____ Adapted |

**10 YEARS AND OLDER ALSO INCLUDE HOME MANAGEMENT**

| (Therapist) |

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**Occupational and Physical Therapy Evaluation**

Shriners Hospitals for Children

Galveston Burns Hospital

Activities of Daily Living

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References

 Suppliers 
b. B&L Engineering, 3002 Dow Ave, Ste 416, Tustin, CA 92780.