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Efficacy of inpatient burn rehabilitation: A prospective pilot study examining range of motion, hand function and balance

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ABSTRACT

Purpose: To examine the effect of inpatient rehabilitation therapy on range of motion, hand function and balance in the burn population.

Methods: This study utilizes a prospective longitudinal design. Inclusion criteria are adults admitted to a regional inpatient rehabilitation hospital with a primary diagnosis of burn injury. Demographic and medical data are collected. Primary outcomes include range of motion at four joints (shoulder, elbow, hip, knee), hand function (Jebsen Taylor Hand Test) and balance (Berg Balance Scale). Outcomes are measured at admission and discharge. Students' *t*-test is used to determine significant differences in outcomes from admission to discharge.

Results: Eleven subjects meet inclusion criteria. The mean age is 50 years, rehabilitation length of stay is 35 days and total body surface area burned is 41%. Subjects demonstrate significant improvements in range of motion, hand function and balance from admission to discharge ($p < 0.05$).

Conclusions: Specific functional measures, range of motion, hand function and balance, demonstrate significant improvement during inpatient rehabilitation. Future work is needed to investigate other functional benefits of rehabilitation and to compare the impact of inpatient rehabilitation to other therapeutic interventions.

1. Introduction

Advances in acute burn care have improved survival rates after severe burns [1]. As a result, the role of rehabilitation has become increasingly important [1–3]. Severe burn survivors often undergo a prolonged course of rehabilitation that begins at the acute care hospital, transitions to an inpatient rehabilitation facility and is completed as an outpatient [2]. The effectiveness of inpatient rehabilitation on burn-specific functional outcomes is not well documented in the literature. Inpatient rehabilitation improves burn survivors' overall function evidenced by improvement in global functional scales such as the FIM™ [1,4]. The FIM consists of 18 items assessing six areas of function that spans motor and cognitive domains. The FIM is a global functional instrument and is not standardized in the burn population [5]. While used in a variety of rehabilitation settings and diagnoses, it does not take into account functional limitations specific to burn

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injuries, including hypertrophic scarring, contractures, body image and fine motor hand function [6]. The FIM is then often not used alone in its entirety to capture recovery of more specific impairments. Important burn-related impairments include joint contractures, hand function and balance [2,7,8].

Contractures are one of the most common impairments following burn injury [9]. Contractures at the large joints (shoulder, elbow, hip and knee) impair functional mobility and activities of daily living (ADL). Schneider found that 38% of burn survivors in an acute care setting developed at least one contracture at discharge [7]. Investigators have studied various treatment approaches for contracture prevention [10–13], including splinting, serial casting [12,14–23], range of motion exercise [18,24] and surgical correction [25–34]. However there is limited data regarding functional outcomes following inpatient rehabilitation treatment of contractures at the large joints. These techniques and modalities are often used together to treat contractures.

One of the most common areas of the body burned is the hand [35]. Hand burns impair strength, range of motion, fine motor function, and ADLs [8,36,37]. Treatment approaches include splinting as well as strengthening and range of motion exercises. Investigators have studied the effects of surgical techniques on hand function relating to burns using the Jebsen Hand Function Test [38]. The Jebsen Hand Function Test assesses performance of tasks resembling ADL in populations ranging from healthy adults to those with disease states affecting hand function including rheumatoid arthritis and strokes [39–41]. It is a valid and reliable instrument, and normative data are available for age and gender [42,43]. Because of the complex nature of tasks performed by the hand, the Jebsen Hand Function Test can better reflect true functional status of the hands rather than range of motion. The effect of inpatient rehabilitation on hand function has not been assessed in the literature.

In the authors' experience, burn survivors demonstrate impaired balance in rehabilitation. Balance is a function of multiple factors including tactile sensation, proprioception, muscle strength, joint mobility and cognition. All of these factors are potentially affected in severe burn injury. Complications of severe burn injuries including prolonged hospitalization, poor nutrition, pain and neuropathies can further worsen balance. Impaired balance retards functional mobility, safety and ultimately independence. The Berg Balance Scale measures balance by assessing performance of functional tasks [44]. The scale is used in a wide range of populations including the elderly, stroke and Parkinson's patients and has excellent correlation with the Barthel Index, FIM, and gait speed [45–48]. There is no literature examining the effect of inpatient rehabilitation on balance in burn injury.

The purpose of this study is to examine the effect of inpatient rehabilitation therapy on range of motion, hand function and balance in the burn population.

2. Methods

This study utilizes a prospective longitudinal design. Criteria for inclusion are admission to a regional inpatient rehabilitation hospital with a primary diagnosis of burn injury and age of 18 years or older. Subjects with more than one inpatient rehabilitation admission, not transferred for surgical contracture release and with more than 40 days between readmissions, were treated as separate rehabilitation stays for analysis purposes.

All subjects received standard of care inpatient rehabilitation. Rehabilitation therapy treatments are performed by physical and occupational therapists 3 h daily, 5 days per week. Interventions are tailored to each patient's individualized functional goals and include scar massage, range of motion, strengthening, functional mobility, gait training, balance activities, fine motor activities, splinting, compression garment treatment and ADL.

Demographic (age, gender and race) and medical data (burn etiology, percent total body surface area burned (TBSA), rehabilitation length of stay, inhalation injury and number of major joint contractures) are collected on all subjects. Primary outcomes include range of motion, hand function and balance. Outcomes are measured at admission and discharge.

Range of motion data is collected at four joints, the shoulder, elbow, hip and knee. The specified joints are examined bilaterally for a total of eight joints studied per subject. Passive range of motion at each joint is measured using a goniometer with a standardized technique [49]. At each joint specific muscle actions (i.e. flexion/extension) are investigated. Flexion and extension are measured at the elbow and knee. Flexion and abduction are measured at the shoulder and hip. The most restricted muscle action at a given joint is assigned a contracture severity rating. Ratings are determined by dividing the normal range of motion value equally in thirds (mild, moderate, severe) (Table 1). Only joints affected by the burn injury are included in the analysis. Joints with normal range of motion on admission are excluded from analysis. In addition, joints without range of motion data recorded are treated as normal and are also excluded from analysis.

Hand function is measured using the Jebsen Hand Function Test (JHFT. It is a seven-item timed evaluation of fine-motor, weighted and non-weighted hand functions related to ADL. The JHFT incorporates functional tasks such as writing, manipulation of various small objects, handling of weighted and non-weighted objects, and simulated feeding. Tasks are measured with a stopwatch. Results are recorded as time for completion. Data is grouped by dominant and non-dominant hand. Times are compared with normative data by age [42,43]. Admission JHFT was obtained for all subjects. For those with

Table 1 – Range of motion severity ratings by joint muscle action.

Joint	Muscle action	Severity rating		
		Mild	Moderate	Severe
Shoulder	Flexion	120 to 180	60 to 119	<60
	Abduction	120 to 180	60 to 119	<60
Elbow	Flexion	93 to 140	46 to 92	<46
	Extension	−140 to −93	−46 to −92	>−46
Hip	Flexion	67 to 100	34 to 66	<34
	Abduction	26 to 40	13 to 25	<13
Knee	Flexion	100 to 150	50 to 99	<50
	Extension	−150 to −100	−99 to −50	>−50

abnormal admission test, a discharge JHFT is performed as well.

Balance is measured using the Berg Balance Scale, a 14-item battery of tasks related to ADLs. Each task is scored from zero to four, with zero the lowest and four the highest functional level. A composite score of 0–20 is categorized as a high fall risk, 21–40 as a medium fall risk, and 41–56 as a low fall risk [44,50,51]. Subjects with missing or incomplete Berg Balance Scale assessments were excluded from analysis.

2.1. *Analysis*

For each joint, the contracture severity ratings were converted to a numerical score (normal = 0; mild = 1; moderate = 2; severe = 3). The number and severity of contractures at each of the studied joints on admission and discharge are tabulated. The numerical contracture rating was matched by subject and compared on admission and discharge for each joint. Improvement across severity ratings were compared from admission to discharge and analyzed graphically and statistically.

Student's *t*-test was used to assess for significant differences in mean contracture severity ratings for each of the eight joints, Jebsen hand scores and Berg Balance Scale scores between admission and discharge. Chi-squared analysis is used to determine significant differences in Berg balance severity ratings between admission and discharge. A *p*-value of 0.05 was used for statistical significance.

3. Results

Eleven subjects meet inclusion criteria. Two of these subjects had two separate admissions and data for each admission is included. These two patients were transferred to acute care because of acute medical issue that necessitated acute hospital level of care. One patient was transferred for bacteremia and colitis, and the other for grafting of a non-healing donor site.

Demographic information is shown in Table 2. The mean age is 52 years, with a median of 49 years (interquartile range: 43, 63), and 45% of the population is male. The mean total body surface area burned is 41%, with a median of 28% (20%, 70%). Twenty-seven percent of subjects experienced inhalation injury. The mean length of inpatient rehabilitation stay is 26 days with a median of 16 days (15, 29). The mean number of affected joints on admission per subject is 4.

A flow chart details the total number of joints studied (Fig. 1). Joints unaffected by the burn injury were excluded from the study ($n = 43$). Joints without any data recorded on admission were treated as unaffected joints and also excluded from analysis ($n = 8$). A total of 53 joints were studied. All patients demonstrated impaired range of motion in at least two joints. (Fig. 2) All joints had significant improvement in range of motion from admission to discharge ($p < 0.05$). Table 3 shows the change in contracture severity ratings from admission to discharge for each joint. Lower extremity joints had a greater improvement in contracture severity rating (0.85, 1.00) than upper extremity joints (0.75, 0.58). In addition, 28 joints improved by one severity level and seven joints improved by two severity levels from admission to discharge. No joints worsened from admission to discharge. Eighteen joints did not show any change from admission to discharge (6 shoulders, 5 elbows, 4 knees, 3 hips) (Fig. 3).

Admission Jebsen Hand Function Test was abnormal in six patients. All subjects with normal admission Jebsen Hand Function Test exhibited no upper extremity burns. Mean Jebsen Hand Function Test times improved by 42% in the dominant hand and 33% in the non-dominant hand from admission to discharge, both of which are significant differences ($p < 0.05$). There was an improvement in mean time of 37 s for both dominant and non-dominant hands between admission and discharge. Results at discharge were slower than normative times for healthy adults (Table 4).

Berg Balance Scores were obtained for nine of the patients. All subjects showed increased Berg Balance scores from admission to discharge. The mean score improved from a medium fall risk (26.1) on admission to a low fall risk (43.3) on discharge (Table 4). The distribution of fall risk categorization improves from admission to discharge, with the majority of patients in low and moderate risk categories on discharge compared to moderate and high risk categories on admission (Fig. 4). Chi-square analysis of fall risk categorization showed a chi-square value of 28.1 with a *p*-value <0.001.

Table 2 – Demographics and medical characteristics.

Category	Value
Age, mean years	52
Gender, percent male	45
Length of inpatient rehabilitation stay, mean days	26
Total body surface area burned, mean percent	41
Inhalation injury, percent	27
Average number of joints affected	4

4. Discussion

This pilot study is the first examination in the literature of the effect of inpatient rehabilitation on burn-specific functional outcomes, including balance, range of motion and hand function. These outcomes are concepts that patients, families, caregivers and payers alike can understand. Evaluating these three outcomes elucidates specific functional impairments and enables a richer understanding of global functional measures previously reported in the literature [1,4,6]. The findings of this study demonstrate significant improvement in joint contractures, hand function and balance with inpatient rehabilitation.

Joint contractures following burn injuries remain a major cause of functional impairment. Leblebici found joint contractures impacts a burn patient's physical functioning, bodily pain and vitality [9]. Most contractures are theoretically preventable, and significant effort is made during the acute hospitalization and inpatient rehabilitation period to improve or prevent them. Patients involved in this study had multiple joint contractures on admission and demonstrated statistically and clinically significant improvements in range of motion during inpatient rehabilitation. There is a lack of

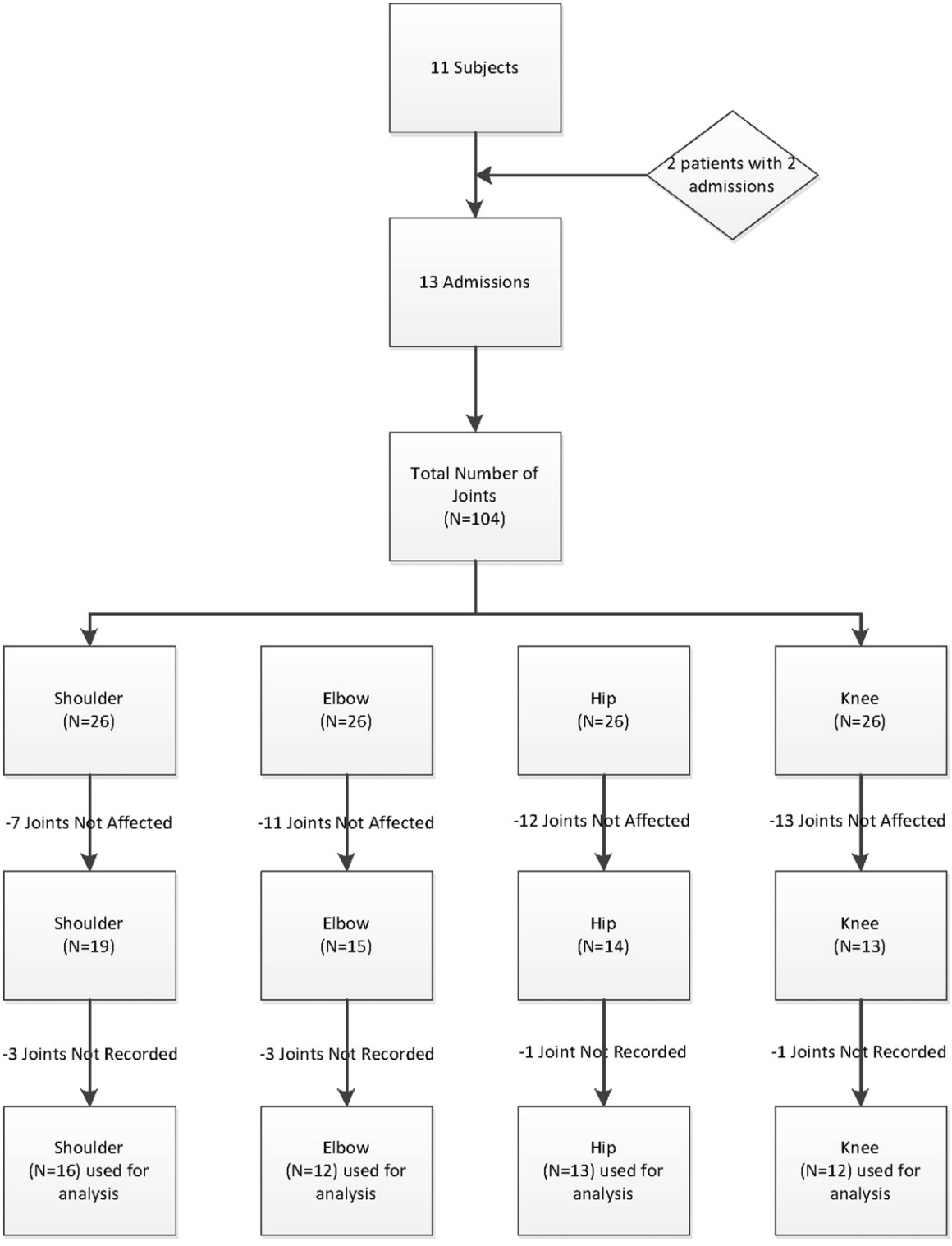

Fig. 1 – Flow chart of joint range of motion data inclusion methodology.

literature on the impact of inpatient rehabilitation on burn contractures, as this pilot study provides the first evidence of its effectiveness. In the surgical literature, Kraemer found that surgical intervention on joint contractures resulted in 88% of joints improved to normal or functional level, and 12% resulted in unsatisfactory outcomes [52]. In comparison, this study examined a conservative treatment approach to contractures and showed that 35–55 (64%) improved and no joints worsened their contracture severity rating.

The management of contractures includes both rehabilitation and surgical interventions. These methods are used in a complementary fashion depending on the clinical course of the patient's contracture. Severe contractures often ultimately benefit from surgical intervention, but rehabilitation efforts

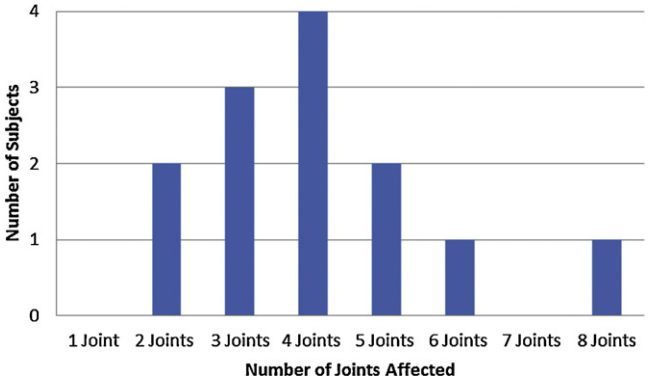

Fig. 2 – Distribution of joints affected.

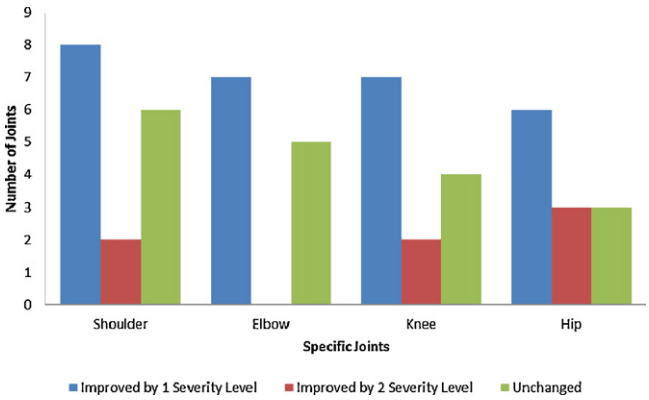

Fig. 3 – Contracture improvement by joints.

such as stretching exercise, casting and splinting are often utilized prior to and in conjunction with surgical management. In such conditions where surgical and rehabilitation techniques are used together, it is difficult to discern the independent impact of rehabilitation on contracture management. This study examines the impact of inpatient rehabilitation where subjects were treated solely with rehabilitation and not surgical interventions. Therefore we are able to discern the independent impact of rehabilitation on contractures.

There have been limited studies that provide longitudinal assessment of hand function after burn injury, and most do not provide functional outcome information. The Jebsen Hand Test uses simulated ADL to assess hand function, and has been used in other studies to assess functional outcomes after hand burns [36,37,42]. Holavanahalli found ADL and work performance correlated with objective measurements of the Jebsen Hand Test [37]. This study found that at inpatient rehabilitation discharge, patients' Jebsen Hand Test scores were below the normative data, but demonstrated significant improvements from admission. Studies of deep full-thickness hand burns showed scores below norms but, in spite of these scores, almost half of all patients are fully independent in ADL and able to work [37]. The Jebsen Hand Test assesses fine motor tasks and therefore may not well represent ADL's and other gross motor tasks. The improvement in Jebsen Hand Test scores represents gains in fine motor hand function. Fine motor function may be more important for select patients depending on their specific occupational requirements.

Similar to the other two outcomes in this study, the Berg Balance Scale has not been widely studied in the burn population as a measure of functional outcome. In other populations such as stroke, the Berg Balance Scales is predictive of clinical and functional outcomes such as length of stay, discharge destination, motor ability and disability level [48]. Given the lack of a burn specific balance scale, the Berg Balance Scale was then used. In this study, patients demonstrated increases in both raw Berg Balance Scores (mean: 17 points) as well as fall risk categories. Studies have found that a change of eight points on the Berg Balance Score correlate to a meaningful clinical change [53]. These findings suggest an overall functional improvement in balance with inpatient rehabilitation. It is beyond the scope of this study to delineate the multifactorial etiology of the balance impairment of each subject. However, further studies are needed to address the validity of using the Berg Balance Scale as a predictor of other functional outcomes in the burn population.

Table 3 – Joint contracture severity ratings on admission and discharge.

Joint	*n*	Mean Admission Contracture Score	Mean Discharge Contracture Score	Improvement mean	*p*-Score
Shoulder	16	1.81	1.06	0.75	0.001
Elbow	12	1.42	0.83	0.58	0.002
Knee	13	2.00	1.15	0.85	0.001
Hip	12	1.92	0.92	1.00	0.001

Table 4 – Jebsen hand function times and Berg balance scores admission and discharge results.

	n	Mean admission data	Mean discharge data	Mean value changes	Normative value	*p*-Value
Jebsen Hand Function Times						
Dominant hand, seconds	6	89	52	37	37.8	0.037
Non-dominant hand, seconds	6	112	74	38	60.2	0.009
Berg Balance Scores	9	26	43	17	High Risk of Falls 0–20 Medium Risk of Falls 21–40 Low Risk of Falls 41–56	0.003

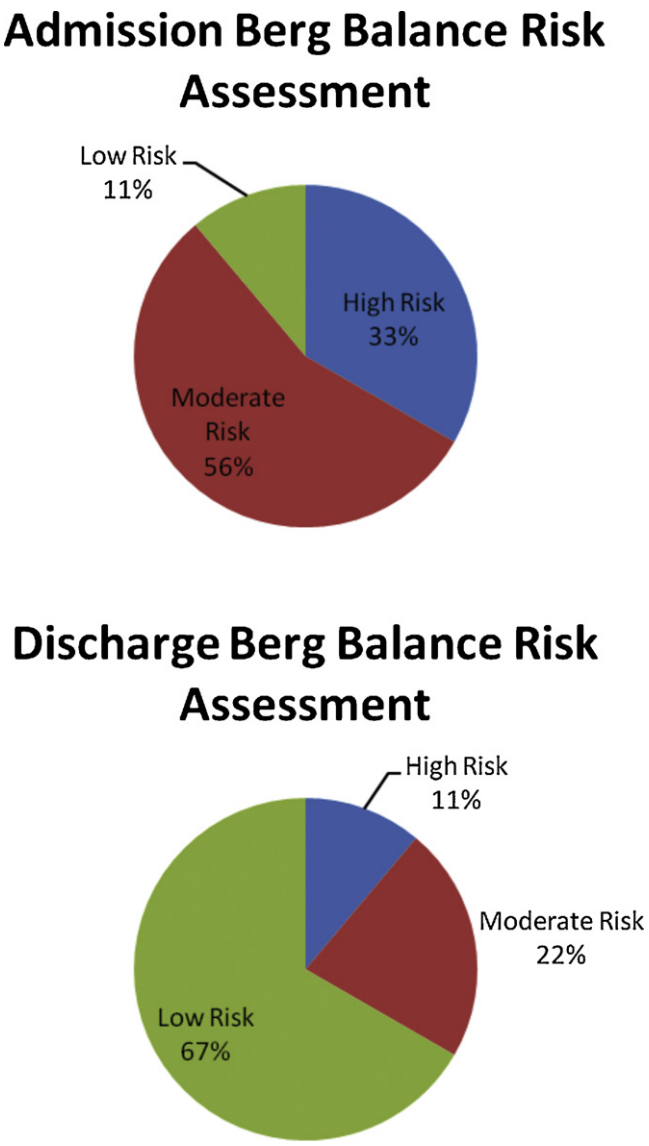

Fig. 4 – Berg Balance Risk Assessment on Admission and Discharge. *Low Risk denotes a score between 0 and 20, moderate risk 21 and 40, and high risk 41 and 56.

This study used objective measures of specific functional domains that provide a more detailed assessment of functional outcome, whereas previous literature on long-term outcomes after burn injuries, such as contractures, has largely focused on surgical techniques for correction of scar contractures and use range of motion as an outcome measure [26,27,32]. Given the significant improvement in contractures, hand function and balance with inpatient rehabilitation, this study provides evidence for the use of inpatient rehabilitation as a first line non-invasive treatment for patients with significant functional impairments from burns. Future studies would further our understanding of inpatient rehabilitation by utilizing a larger sample size and examining predictors of functional outcomes. Comparison of surgical and inpatient rehabilitation interventions for contractures also deserves further investigation.

A limitation of this study is its small sample size. However, this is reflected in the reduction of burn injuries in developed countries. Recent incidence reports show burn injuries to have a global incidence of 1.1 per 100,000 population, however that drops to 0.19 per 100,000 population in the Americas, and burn injuries requiring medical attention follow similar trends [54]. A longer recruitment period or multi-center trial may be needed in the future to increase sample size. A larger sample size would enable a multivariate analysis that could control for demographic and medical variables. Also, this study lacks a standardized therapy and control group. Standardization of inpatient rehabilitation is difficult, as no two burn injuries are identical and rehabilitation programs are individualized to treat each patient's specific impairments. This study only addresses functional outcomes in inpatient rehabilitation and does not address outcomes related to other rehabilitation settings, such as acute care, skilled nursing facilities or outpatient therapy. Given the lack of literature on functional outcomes in any of these other rehabilitation settings, future studies may compare the relative efficacy of rehabilitation outcomes across different settings. The findings of this study are limited to the outcome measures used and the conclusions that can be drawn from these measures. For example, hand function is complex and the Jebsen Taylor Hand Test measures speed of hand tasks and may not correlate with other aspects of upper extremity function [55]. Future study may examine the impact of burn specific function on global functional outcomes and psychosocial outcomes.

As policy makers and payers are increasingly focused on the cost effectiveness of healthcare, they will likely place a greater emphasis on outcomes when determining resource allocation. Outcome measures such as range of motion, hand function and balance are functionally important indicators of the efficacy of inpatient rehabilitation following burn injury. This prospective pilot study demonstrates significant improvements in all three functional domains during inpatient rehabilitation. This data underscores the value of intensive rehabilitation therapy as a first-line approach to the treatment of burn impairments.

Conflict of interest statement

No authors have any financial or personal relationships with other people or organization that could inappropriately influence their work.

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REFERENCES

[1] van Baar ME, Essink-Bot ML, Oen IM, Dokter J, Boxma H, van Beeck EF. Functional outcome after burns: a review. Burns J Int Soc Burn Injuries 2006;32(1):1–9.

[2] Esselman PC, Thombs BD, Magyar-Russell G, Fauerbach JA. Burn rehabilitation: state of the science. Am J Phys Med Rehabil 2006;85(4):383–413.
[3] Esselman PC. Burn rehabilitation: an overview. Arch Phys Med Rehabil 2007;88(12 Suppl 2):S3–6.
[4] Sliwa JA, Heinemann A, Semik P. Inpatient rehabilitation following burn injury: patient demographics and functional outcomes. Arch Phys Med Rehabil 2005;86(10):1920–3.
[5] Choo B, Umraw N, Gomez M, Cartotto R, Fish JS. The utility of the functional independence measure (FIM) in discharge planning for burn patients. Burns J Int Soc Burn Injuries 2006;32(1):20–3.
[6] Nakamura DY, Esselman PC, Mann R, Engrav LH. The inadequacy of the FIM (functional independence measure) for burns. J Burn Care Rehabil 1997;18.
[7] Schneider JC, Holavanahalli R, Helm P, Goldstein R, Kowalske K. Contractures in burn injury: defining the problem. J Burn Care Res 2006;27(4):508–14.
[8] Schneider JC, Holavanahalli R, Helm P, O'Neil C, Goldstein R, Kowalske K. Contractures in burn injury. Part II. Investigating joints of the hand. J Burn Care Res 2008;29(4):606–13.
[9] Leblebici B, Adam M, Bagis S, Tarim AM, Noyan T, Akman MN, et al. Quality of life after burn injury: the impact of joint contracture. J Burn Care Res 2006;27(6): 864–8.
[10] Cooper S, Paul EO. An effective method of positioning the burn patient. J Burn Care Rehabil 1988;9(3):288–9.
[11] Helm PA, Kevorkian CG, Lushbaugh M, Pullium G, Head MD, Cromes GF. Burn injury: rehabilitation management in 1982. Arch Phys Med Rehabil 1982;63(1):6–16.
[12] Serghiou MA, McLaughlin A, Herndon DN. Alternative splinting methods for the prevention and correction of burn scar torticollis. J Burn Care Rehabil 2003;24(5):336–40. discussion 322.
[13] Bunchman II HH, Huang TT, Larson DL, Lewis SR. Prevention and management of contractures in patients with burns of the neck. Am J Surg 1975;130(6):700–3.
[14] Richard R, Staley M, Miller S, Warden G. To splint or not to splint—past philosophy and present practice. Part I. J Burn Care Rehabil 1996;17(5):444–53.
[15] Richard R, Staley M, Miller S, Warden G. To splint or not to splint: past philosophy and current practice. Part II. J Burn Care Rehabil 1997;18(1 Pt 1):64–71.
[16] Richard R, Staley M, Miller S, Warden G. To splint or not to splint—past philosophy and present practice. Part III. J Burn Care Rehabil 1997;18(3):251–5. discussion 250.
[17] Fujimori R. Effect of adhesive splint in preventing scar contracture. J Burn Care Res 1984;5(1):50–4.
[18] Richard R, Miller S, Staley M, Johnson RM. Multimodal versus progressive treatment techniques to correct burn scar contractures. J Burn Care Rehabil 2000;21(6):506–12.
[19] Manigandan C, Gupta AK, Venugopal K, Ninan S, Cherian RE. A multi-purpose, self-adjustable aeroplane splint for the splinting of axillary burns. Burns J Int Soc Burn Injuries 2003;29(3):276–9.
[20] Van Straten O, Sagi A. ''Supersplint'': a new dynamic combination splint for the burned hand. J Burn Care Rehabil 2000;21(1 Pt 1):71–3. discussion 70.
[21] Forsyth-Brown E. The slot-through splint. Physiotherapy 1983;69(2):43–4.
[22] Guild S. A new splinting approach for dorsal foot burns. J Burn Care Rehabil 2001;22(6):454–6.
[23] Bhattacharya S, Bhatnagar SK, Chandra R. Postburn contracture of the neck—our experience with a new dynamic extension splint. Burns J Int Soc Burn Injuries 1991;17(1):65–7.
[24] Celis MM, Suman OE, Huang TT, Yen P, Herndon DN. Effect of a supervised exercise and physiotherapy program on surgical interventions in children with thermal injury. J Burn Care Rehabil 2003;24(1):57–61. discussion 56.
[25] Greenhalgh DG, Gaboury T, Warden GD. The early release of axillary contractures in pediatric patients with burns. J Burn Care Rehabil 1993;14(1):39–42.
[26] Hallock GG. A systematic approach to flap selection for the axillary burn contracture. J Burn Care Rehabil 1993;14(3):343–7.
[27] Tanaka A, Hatoko M, Tada H, Kuwahara M. An evaluation of functional improvement following surgical corrections of severe burn scar contracture in the axilla. Burns J Int Soc Burn Injuries 2003;29(2):153–7.
[28] Nisanci M, Er E, Isik S, Sengezer M. Treatment modalities for post-burn axillary contractures and the versatility of the scapular flap. Burns J Int Soc Burn Injuries 2002;28(2):177–80.
[29] Madhuri V, Dhanraj P. Correction of post burns contracture of wrist with Ilizarov method. Burns J Int Soc Burn Injuries 1998;24(6):576–8.
[30] Ertas NM, Bozdogan N, Erbas O, Uscetin I, Kucukcelebi A, Celebioglu S. The use of subcutaneous pedicle rhomboid flap in the treatment of postburn scar contractures. Ann Plastic Surg 2004;53(3):235–9.
[31] Suliman MT. Experience with the seven flap-plasty for the release of burns contractures. Burns J Int Soc Burn Injuries 2004;30(4):374–9.
[32] Agarwal R, Chandra R. Latissimus dorsi myocutaneous flap reconstruction of neck and axillary burn contractures. Plastic Reconstr Surg 2000;106(5):1216.
[33] Iwuagwu FC, Wilson D, Bailie F. The use of skin grafts in postburn contracture release: a 10-year review. Plastic Reconstr Surg 1999;103(4):1198–204.
[34] Frame JD, Still J, Lakhel-LeCoadou A, Carstens MH, Lorenz C, Orlet H, et al. Use of dermal regeneration template in contracture release procedures: a multicenter evaluation. Plastic Reconstr Surg 2004;113(5):1330–8.
[35] Smith MA, Munster AM, Spence RJ. Burns of the hand and upper limb—a review. Burns 1998;24(6):493–505.
[36] van Zuijlen PP, Kreis RW, Vloemans AF, Groenevelt F, Mackie DP. The prognostic factors regarding long-term functional outcome of full-thickness hand burns. Burns 1999;25(8):709–14.
[37] Holavanahalli RK, Helm PA, Gorman AR, Kowalske KJ. Outcomes after deep full-thickness hand burns. Arch Phys Med Rehabil 2007;88(12 Suppl 2):S30–5.
[38] Omar MT, Hassan AA. Evaluation of hand function after early excision and skin grafting of burns versus delayed skin grafting: a randomized clinical trial. Burns J Int Soc Burn Injuries 2011.
[39] Pereira EA, Raja K, Gangavalli R. Effect of training on interlimb transfer of dexterity skills in healthy adults. Am J Phys Med Rehabil/Assoc Acad Physiatrists 2011;90(1):25–34.
[40] Jain A, Ball C, Freidin AJ, Nanchahal J. Effects of extensor synovectomy and excision of the distal ulna in rheumatoid arthritis on long-term function. J Hand Surg 2010;35(9):1442–8.
[41] Gao KL, Ng SS, Kwok JW, Chow RT, Tsang WW. Eye-hand coordination and its relationship with sensori-motor impairments in stroke survivors. J Rehabil Med Official J UEMS Eur Board Phys Rehabil Med 2010;42(4):368–73.
[42] Jebsen RH, Taylor N, Trieschmann RB, Trotter MJ, Howard LA. An objective and standardized test of hand function. Arch Phys Med Rehabil 1969;50(6):311–9.
[43] Hackel ME, Wolfe GA, Bang SM, Canfield JS. Changes in hand function in the aging adult as determined by the Jebsen Test of Hand Function. Phys Ther 1992;72(5):373–7.
[44] Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. Can J Public Health 1992;83(Suppl 2):S7–11.

[45] Jacobson BH, Thompson B, Wallace T, Brown L, Rial C. Independent static balance training contributes to increased stability and functional capacity in community dwelling elderly people: a randomized controlled trial. Clin Rehabil 2011.
[46] Byun SD, Jung TD, Kim CH, Lee YS. Effects of the sliding rehabilitation machine on balance and gait in chronic stroke patients – a controlled clinical trial. Clin Rehabil 2010.
[47] Leddy AL, Crowner BE, Earhart GM. Functional gait assessment and balance evaluation system test: reliability, validity, sensitivity, and specificity for identifying individuals with Parkinson disease who fall. Phys Ther 2011;91(1):102–13.
[48] Blum L, Korner-Bitensky N. Usefulness of the Berg Balance Scale in stroke rehabilitation: a systematic review. Phys Ther 2008;88(5):559–66.
[49] Model system for burn injury rehabilitation national database data dictionary. Available from: http://bms-dcc.uchsc.edu [cited 8, 2006 May].
[50] Berg KO, Maki BE, Williams JI, Holliday PJ, Wood-Dauphinee SL. Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil 1992;73(11):1073–80.
[51] Riddle DL, Stratford PW. Interpreting validity indexes for diagnostic tests: an illustration using the Berg Balance Test. Phys Ther 1999;79(10):939–48.
[52] Kraemer MD, Jones T, Deitch EA. Burn contractures: incidence, predisposing factors, and results of surgical therapy. J Burn Care Rehabil 1988;9(3):261–5.
[53] Conradsson M, Lundin-Olsson L, Lindelof N, Littbrand H, Malmqvist L, Gustafson Y, et al. Berg Balance Scale: intrarater test–retest reliability among older people dependent in activities of daily living and living in residential care facilities. Phys Ther 2007;87(9):1155–63.
[54] WHO. Global burden of disease 2004 summary tables. Geneva: World Health Organization; 2008.
[55] Davis Sears E, Chung KC. Validity and responsiveness of the Jebsen-Taylor Hand Function Test. J Hand Surg 2010;35(1):30–7.