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ORIGINAL REPORT

BURN SURVIVORS' PULMONARY AND MUSCULAR IMPAIRMENT, EXERCISE TOLERANCE AND RETURN-TO-WORK FOLLOWING MEDICAL-VOCATIONAL REHABILITATION: A LONG-TERM FOLLOW-UP

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Objective: **To follow up the long-term outcome in return-to-work (RTW) rate in burn-injury patients, and to determine the degree of impairment in pulmonary and muscular function and exercise tolerance.**

Design: **A prospective, longitudinal follow-up study without a control group.**

Patients: **Twenty-five burn-injury patients referred for medical-vocational rehabilitation.**

Methods: Return-to-work rate was followed after completed medical-vocational rehabilitation. Pulmonary function was evaluated with spirometry, diffusing capacity and radio spirometry. Exercise capacity was determined using a bicycle ergometer. Muscle functions evaluated in the arms and legs were: isokinetic torque, isometric strength, endurance and muscular strength utilization.

Results: **Return-to-work rate was 87%. During bicycle exercise tests the patients, on average, reached their expected workloads. The dominating lung function abnormality observed on lung scintigraphy was delayed wash-out time of inhaled radioactive xenon gas, suggesting airway obstruction. All tests of shoulder-flexor and knee-extensor muscle function showed large minimum–maximum differences. Mean isometric endurance of shoulder flexors was lower than mean of references, and isokinetic knee extensor torques were slightly lower.**

Conclusion: **High return-to-work rates can be achieved after burn injury requiring hospital-ward care. Despite measurable impairments in muscle strength/endurance and pulmonary function in a substantial proportion of these patients, overall normal bicycle exercise capacity was observed except for a few cases.**

Key words: burn injury; return to work; medical rehabilitation; vocational rehabilitation; cardio-pulmonary exercise capacity; lung scintigraphy; pulmonary function; muscle function.

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MAIN MESSAGE

For jobs involving physical load, functions related to respiratory and cardiovascular capacity are important. Burn-injury patients have often been exposed to smoke inhalation and/or treated with respirator for long periods, hence pulmonary functions and exercise capacity was investigated post-burn. Mobility is another important activity related to job demands, and since extremities are often injured, measurements of muscle power and endurance were taken in all extremities. Twenty-five consecutive former serious burn-injury patients referred for medical-vocational rehabilitation were studied. Pronounced variations occurred in muscular strength and endurance of extremities – from weak to powerful – where arm endurance was most affected. Pulmonary function in general was restored. Bicycle exercise performance was on average within the normal range except for a few cases. A high return-to-work rate can be achieved in a cohort of seriously compromised thermal injury patients following team-based, individualized, medical-vocational rehabilitation.

Information on return-to-work (RTW) after severe burn injury is scarce in current books on vocational rehabilitation. This may be due to the paucity of original articles on burn injury that include detailed RTW data among the outcome parameters (1–5).

Some studies of extensive burns have shown that muscle strength is reduced after burn injury (6, 7) and that various exercise training programmes improve activity limitations (8–11). Functional outcomes after burns are reviewed and classified according to the World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF) (12, 13), showing that impairments in respiration (ICF category: b440) and muscular functions (ICF: b730-49) and exercise tolerance functions (ICF: b455) are common. In addition, clinical experience indicates that many survivors of severe burns experience muscular fatigue. Survivors rated vitality (Short Form 36; SF36) lower than in the normal population (14), as confirmed in other studies (e.g. 8, 15, 16).

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Against this background, a long-term follow-up of the RTW rate of patients treated for burn injury seems relevant. An interdisciplinary clinical setting was chosen with regular cooperation between hospital departments of reconstructive plastic surgery, rehabilitation medicine and clinical physiology. The last phase of the management process included patient participation in a work-oriented medical ("vocational") rehabilitation programme aiming at optimizing the patients' work capacity. Requirements for different professions vary. For jobs involving any degree of physical load, respiration functions and functions related to respiratory and cardiovascular capacity (as required for enduring exertion) are important. Burn-injury patients have often been exposed to smoke inhalation and/or treated with intubation/tracheostomy and ventilated for long periods, supporting the investigation of pulmonary function post-burn. Mobility is another important activity related to job demands, and mobility is related to muscle power and endurance functions. Since, for example, the extremities are often injured, perhaps affecting muscles and tendons and sometimes including impaired body structures, it was felt relevant to take measurements of muscle power and endurance for all extremities. These measurements were taken for use in vocational rehabilitation-goal planning, and as follow-up of important body functions following burn injury.

The aim of this study was to follow up the long-term outcome in RTW rate in burn-injury patients after individualized medical-vocational rehabilitation, and to measure 3 body functions related to physical job demands: pulmonary function, muscle function and exercise capacity.

METHODS

Patients

The characteristics of the patients included in the study are shown in Fig. 1 and Tables I and II. They were treated at the Burns Unit, Karolinska University Hospital between 1996 and 2004. All 29 patients who were in work pre-injury and were assessed to be in need of medical-vocational rehabilitation for being able to return to working life, were consecutively offered inclusion. As shown in Fig. 1, 1 patient died and 3 did not attend admission or major investigations, resulting in a final total of 25 participants. All were gainfully employed before injury, except 1 woman who was married to a farmer and was thus not employed in the usual way. Some patients were excluded as they did not need this specific rehabilitation (Fig. 1); for example, they were able to resume work without specific measures.

Compared with all other thermal burn injury patients treated at the Burns Unit during the same period, with a minimum length of stay of 4 days (Table I), the study group had a larger total body surface area burned (TBSAB) and larger full-thickness burn area. The group contained more patients exposed to smoke inhalation, more patients treated with intubation/tracheostomy, more severe Abbreviated Burn Severity Index (ABSI), and more in-patient days. ABSI is a combination based largely on inhalation injury, depth of injury, sex and age. Although somewhat younger, the present study group was thus not a selection of less-affected patients.

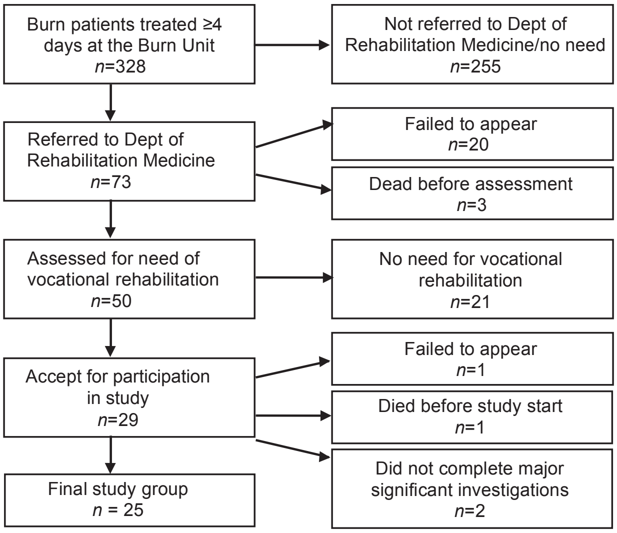

Fig. 1. Flow diagram of study participants.

Sub-acute rehabilitation

On the burn injury ward the patients had daily physiotherapy and occupational therapy. A majority of the patients did not need work-oriented rehabilitation (Fig. 1).

Work-oriented medical rehabilitation (vocational rehabilitation)

After referral to the Department of Rehabilitation Medicine of Karolinska University Hospital, the patients were assessed by a rehabilitation physician. When the patients were admitted to medical-vocational rehabilitation, they were assessed by a multi-professional rehabilitation team (physiotherapist (PT), occupational therapist (OT), social worker, psychologist). Following a team conference, individual work-oriented rehabilitation programmes were decided on and commenced. Individual combinations of physiotherapy, work-oriented oc-

Table I. All thermal burn injury patients, age 20–64 years, with length of stay (LOS) ≥ 4 days compared with study-group patients for the same period

Patient groups	All patients	Study group
Patients, *n*	328	25
Men, *n* (%)	229 (70)	18 (72)
Women, *n* (%)	99 (30)	7 (28)
Age at burn injury, years, median (range)	42 (20–64)	36 (19–64)
Mean, years	42	37
TBSAB, %, median (range)	7 (0–90)	27 (0–68)
Mean, %	13	31
Smoke inhalation, *n* (%)	22 (7)	7 (28)
Intubation/tracheostomy, *n* (%)	67 (20)	14 (56)
Full thickness burn area, *n* (%)	221 (67)	23 (92)
ABSI burn score, median (range)	5 (3–14)	7 (3–11)
Mean	5	7
LOS, days, median (range)	13 (4–124)	45 (5–124)
Mean	20	51

TBSAB: total body surface area burned; ABSI: Abbreviated Burn Severity Index score, maximum burn score 14; LOS: length of stay.

Table II. Consecutive clinical histories of study group

Number	Age at injury, years/Sex	Clinical histories
1	37/M	Self-imposed, burning gasoline, 48% TBSAB, deep facial burn injuries, dialysis, ventilator 36 days.
2	27/F	Down jacket catching fire indoors, 52% TBSAB, ventilator 21 days.
3	47/M	House fire, 27% TBSAB, pneumonia, ventilator 29 days. Inhalation injury.
4	37/M	Car crash with 4 casualties, 18% TBSAB, lung contusion, ventilator 4 days.
5	42/M	Explosion of diesel tank, 30% TBSAB, no ventilator.
6	53/F	Scald burn, 35% TBSAB, ventilator 15 days.
7	39/M	Explosion of tin barrel outdoors, 43% TBSAB, bilateral pneumonias twice, ventilator 27 days.
8	51/M	Barbecue fuel outdoors, 30% TBSAB, no ventilator.
9	25/M	House fire, 4% TBSAB, CPAP, no ventilator. Inhalation injury.
10	26/F	House fire, no cutaneous burn, no ventilator. Inhalation injury.
11	48/F	Clothes catching fire indoors, 23% TBSAB, ventilator 13 days.
12	19/M	Car crash with 4 casualties, 23% TBSAB, cognitive impairment post-burn, CO poisoning, ventilator 4 days. Inhalation injury.
13	29/M	Clothes catching fire outdoors, 25% TBSAB, ARDS, prone position 2 weeks, ventilator 41 days.
14	31/M	Contact burn sauna, 21% TBSAB, no ventilator.
15	27/M	Car crash, 7% TBSAB, no ventilator.
16	32/F	Car crash, fractures, 12% TBSAB. CO poisoning. Post-burn cognitive impairment, no ventilator.
17	25/M	Car crash, 35% TBSAB, ventilator 11 days.
18	19/F	Car crash, 18% TBSAB, no ventilator.
19	48/M	Explosion oil tank indoors, 55% TBSAB, ventilator 27 day. Inhalation injury.
20	53/F	Hot oil, 7% TBSAB, no ventilator.
21	64/M	Barbecue fuel, 50% TBSAB, cardiac arrest, ventilator 40 days, pneumonia twice. Before injury COPD. Inhalation injury.
22	37/M	House fire, 23% TBSAB, smoke inhalation, ventilator 10 days. Inhalation injury.
23	27/M	Hydraulic oil igniting overall indoors, 68% TBSAB, 70 anaesthesia, ventilator 3 days.
24	60/M	Garage fire, 64% TBSAB, pneumonia twice, ventilator 72 days.
25	31/M	Gas explosion indoors, 50% TBSAB, tracheostomy, no ventilator.

TBSAB: % total body surface area burned; CO: carbon monoxide; ARDS: acute respiratory distress syndrome; COPD: chronic obstructive pulmonary disease; M: male; F: female.

cupational therapy, and interventions by the social worker and psychologist were applied. A certain focus was placed on the OT's workplace analyses, including, for example, tasks, work movements, elimination of too-difficult work tasks, application of ergonomic devices, and alterations to the workplace. For impaired muscle function and fitness, the PT designed measures for improvement, both at the department, locally and at home. Extended functional measurements of muscular and pulmonary functions and exercise capacity usually occurred within 1–2 months after admission to the programme. The results of the extended measurements were used as information for planning job targets and adjusting rehabilitation measures. The median time from discharge from the hospital burns ward to functional evaluation was 17 months (range 5–96 months). In the late phase of the vocational rehabilitation, the rehabilitation physician, patient, and public social insurance officer met to follow up and to plan vocational/disability pension. Work-oriented medical rehabilitation of burn survivors is usually complex because the patients alternate between more specific rehabilitation and the need for, for example, surgical release of contractures or other measures. This interrupts and prolongs the rehabilitation process. Information about RTW and/or disability pension was obtained at physicians' follow-up visits and in cooperation with the social insurance officer.

Pulmonary function

Since many patients had inhaled smoke and/or been intubated/tracheotomized (Table I) and many had been ventilated for long periods (Table II), respiration functions (ICF b440) were thoroughly investigated.

Standard lung-function tests were performed in a lung-function laboratory using continuous calibration routines. Total lung capacity (TLC), residual volume (RV), vital capacity (VC), forced expired volume during 1 s ($FEV_{1.0}$) and derived indices were determined. Maximal voluntary ventilation was determined at a respiratory rate of 40/min (MVV_{40}). In addition, carbon monoxide diffusing capacity (DLCO) was assessed. Normal values were calculated following the European Coal and Steel Union guidelines (17). Data from the lung function tests were expressed as percentages of predicted values. A deviation of more than 20% of the predicted values was considered abnormal.

Pulmonary scintigraphy with radio spirometry

Perfusion and ventilation scintigraphy were performed with a dual-headed gamma camera using ^{99m}Tc-labelled macro aggregates of albumin administered intravenously for perfusion. ^{133}Xe gas was inhaled for ventilation, without changing the patients' (supine) position. Relative perfusion (Q' %) and relative ventilation (V' %) for each lung were expressed as percentages of the total respective counts in both lungs, permitting calculation of a V'/Q'- ratio for each lung.

During ventilation the patient breathed into a closed-circuit spirometer into which the ^{133}Xe gas was introduced. When the xenon had equilibrated in the lungs, the spirometer was opened to the air and xenon was gradually "washed out" depending on the tidal volume and degree of gas retention in the lung (radio spirometry). A "wash-out" half time ($T_{½}$) of xenon below 30 s from each lung was considered normal by the laboratory (18).

Bicycle exercise test

A symptom-limited exercise test was performed on a bicycle ergometer, starting at a work-load of 30 W and increasing by 10 W per min until the patient stopped pedalling. The reason for stopping was noted. Transcutaneous oxygen saturation (SpO_2) was recorded at rest, on maximal exercise and immediately after exercise. Normal values for exercise capacity were estimated from sex, age and body weight (19). Data from the exercise tests were expressed as percentages of predicted values. A deviation of more than 20% of the predicted values was considered abnormal.

Muscle function tests

Isokinetic concentric muscle torque (in Nm) was measured (Chattecx Kin-Com® 125 E Plus, Chattecx Corp., Chattanooga, TN, USA) in the shoulder flexors at angular speeds of 30°/s and 90°/s and in the knee extensors at 60°/s. Reference values are available (e.g. 20, 21). Maximum isometric strength (Nm) was recorded in shoulder flexors at a 90° position. Maximum isometric lower-limb extension force (N) was measured (each side separately) in a sitting position with the knee flexed 75° in a special device (Rodby, Enhörna, Sweden), similar to common leg-extension training devices ("leg press"), but with a fixed force-sensitive foot plate. Reference values from a population study are available (22).

Muscle endurance was measured as duration (s) of a standardized isometric contraction of shoulder flexors when sitting with the right upper extremity horizontal and with a standardized weight sleeve giving external load at the level of the distal forearm (2.5 kg for women, 4 kg for men) according to a validated test with reference values for women and men (23, 24).

Individual muscular exertion for a given load was assessed using the muscular strength utilization ratio (MUR%). This is a measure of how much of an individual's shoulder flexor muscle strength capacity is needed to keep the straight upper extremity horizontal with a standardized external weight applied. A high value for MUR% means that relatively more of the individual's muscle strength capacity is required for performing the standardized test (23, 24).

Statistical analysis

Descriptive statistics were used. Lung-function parameters and exercise capacity are presented as percentages of reference values with means and 1 standard deviation (SD).

Ethics

The study was approved by the Ethics Board of Karolinska Hospital (registration 96-125; 99-320). All patients provided written consent.

RESULTS

Return to work

Table III shows RTW rates (87%) and proportions of part/full-time employment. Only 4 subjects were granted full-time disability pension due to burn injury. Age at the time of injury tended to be lower in those who returned to full-time work than in part-time returners (50–80%). Median ages were 27 and 40 years, respectively.

Table III. Work resumption/pension and return-to-work rate in burn-injury patients referred for medical-vocational rehabilitation

	Men: 18	Women: 7	Total: 25
Work resumption 100%, *n*	6	3	9
Work resumption 75–80%, *n*	2	1	3
Work resumption 50–60%, *n*	7	1	8
Work resumption total, *n*	15	5	20
Return-to-work (RTW) rate*, % (*n*)	88 (15/17)	83 (5/6)	87 (20/23)
Old-age pension, *n*	1		
Disability pension, *n*	2	2**	

*RTW rate calculated based on those who had skilled work before injury and had age-related possibility to resume work after injury. Men 18–1 = 17 as 1 achieved old-age-pension. Women 7–1 = 6 as 1 woman was granted disability pension and was not active as skilled worker before injury; is therefore not added to denominator of RTW rate**.

Pulmonary function tests

All 25 patients completed the spirometry examinations. Diffusing capacity (DLCO) was assessed in 20 patients and lung scintigraphy in 21 patients.

Standard lung-function tests (Fig. 2) showed no signs of restrictive impairment in any patient. There were spirometric signs of airway obstruction in 6 patients, with FEV1.0 between 56% and 79% of expected. Only 2/7 patients with inhalation injuries showed reduced FEV1.0: 56% and 60% of expected (patients numbers 9 and 21). DLCO was reduced in 6 patients, between 59% and 78% of expected. Among those with inhalation injuries, the median recorded DLCO was 94% of expected (range 67–97%). The dominating lung-function abnormality observed on lung scintigraphy was delayed wash-out time of inhaled xenon gas, where T1/2 was >40 s (normal <30 s) in 70% of the patients (Fig. 3), suggesting some degree of airway

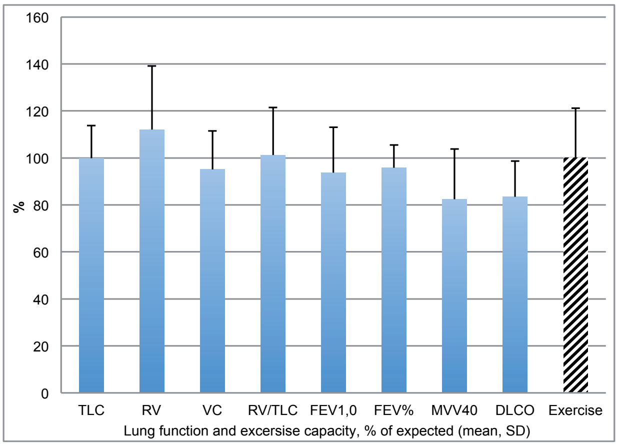

Fig. 2. Lung function as percentage of expected at follow-up in 25 burn patients referred for medical-vocational rehabilitation. Mean, standard deviation (SD). TLC: total lung capacity; RV: residual volume; VC: slow vital capacity; $FEV_{1.0}$: forced expired volume during 1 s; FEV%: $FEV_{1.0}$/VC; MVV40: maximal voluntary ventilation at a rate of 40 breaths/min; DLCO: diffusing capacity of carbon monoxide. Striped column (*right-hand side*) shows symptom-limited exercise capacity on a bicycle ergometer.

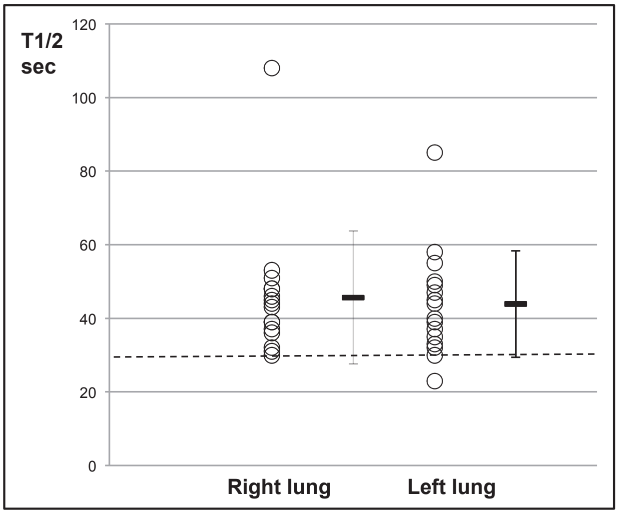

Fig. 3. Wash-out times ($T_{½}$) in s of inhaled xenon gas for each lung during radio spirometry. Solid bars show mean±standard deviation (SD). *Dotted line* represents normal wash-out time.

obstruction. It is notable that 14 of the 21 patients (67%) who performed scintigraphy were smokers.

Table IV. Shoulder muscle functions in burn-injury patients referred for medical-vocational rehabilitation, as % of reference

	% of reference Mean (median)	% of reference Min–Max
Isokinetic shoulder flexor peak torque, Nm, 30°/s, right side, *n* = 19 (4F, 15M)	96.0 (80.4)	14.6–208.8
Isokinetic shoulder flexor peak torque, Nm, 30°/s, left side, *n* = 17 (3F, 14M)	114.7 (91.7)	35.5–247.8
Isokinetic shoulder flexor peak torque, Nm, 90°/s, right side, *n* = 19 (4F, 15M)	96.8 (85.1)	43.9–309.7
Isokinetic shoulder flexor peak torque, Nm, 90°/s, left side, *n* = 17 (3F, 14M)	92.8 (91.1)	28.9–204.4
Isometric shoulder flexor strength, Nm, right side, *n* = 22 (5F, 17M)	111.4 (94.2)	31.2–200.8
Isometric shoulder flexor strength, Nm, left side, *n* = 22 (5F, 17M)	119.0 (110.4)	22.7–204.6
Isometric endurance of shoulder flexors in horizontal position (90°), time start-to-discontinuance (s), right side, *n* = 20 (4F, 16M)	69.0 (54.3)	17.9–187.2

Concentric isokinetic measurements. Nm: newton metre, unit of torque; F: female; M: male.

Table V. Individual muscular strength utilization ratios (MUR%)* for a standardized isometric shoulder flexor load test for men and women of the study

	MUR% Mean (SEM)	MUR% Min–Max (median)	Percentage of expected MUR % (SD) [SEM]	Min–max of percentage of expected MUR % (median)
Men, load 4 kg *n* = 15	54.6 (3.9)	29.4–72.9 (55.9)	92.2 (27.1) [7]	48.0–133.5 (89.5)
Women, load 2.5 kg *n* = 5	75.9 (5.8)	53.9–88.3 (79.3)	95.4 (16.1) [7.2]	69.1–113.2 (98.7)
Men and women *n* = 20			93.0 (24.5) [5.5]	48.0–133.5 (96.0)

A percentage below 100 implies that the subject uses less of his/her individual strength than expected to complete the standardized load test – less effort needed. More than 100% of expected implies the use of more of his/her strength to complete the load test – more effort needed. Measurements were compared with age- and sex-related reference values (23, 24). Note the large range between Min and Max.

*Calculation of MUR% = (moment of external load + moment of weight of arm/forearm/hand segments) × 100 divided by the moment caused by maximal isometric shoulder flexor strength – with upper extremity in horizontal position. The spread of reference mean MUR% for men aged: 19–34 years was SEM 2.6 (m = 54.6), 35–44 years SEM 2.5 (m = 58.9), 45–65 years SEM 6.3 (m = 69.0) and all men SEM 2.9 (m = 61.0). For women in same age classes: SEM 4.9 (m = 81.8), SEM 3.1 (m = 66.6), SEM 3.6 (m = 78.8), and for all women SEM 2.5 (m = 75.6).

Table VI. Lower-extremity muscle functions in burn-injury patients referred for medical-vocational rehabilitation, as % of reference value

	% of reference Mean (median)	% of reference Min–Max
Isokinetic concentric knee extension torque 60°/s (Nm), right side, *n* = 21 (5F, 16M)	78.3 (72.4)	8.0–138.7
Isokinetic concentric knee extension torque 60°/s (Nm), left side, *n* = 19 (4F, 15M)	77.4 (79)	6–140
Isometric lower-limb extension force (N) right side, *n* = 22 (5F, 17M)	118.0 (108)	21–212
Isometric lower-limb extension force (N) left side, *n* = 22 (5F, 17M)	95.8 (100.5)	18–159

Nm: newton metre, unit of torque; Newton (N): unit of force; M: male; F: female.

Exercise capacity

The bicycle exercise tests were performed by 18 patients. All patients returning to work were able to perform these tests. On average, the patients reached their expected workloads (Fig. 2) without significant desaturation (SpO_2). Reasons for stopping pedalling were mostly leg fatigue or shortness of breath. Only 2 patients showed really impaired exercise performance, 64% and 65% of expected (patient numbers 12 and 21).

Muscle function

Tests of shoulder-flexor muscle function (Table IV) showed big differences between minimum and maximum outcomes. The mean isometric endurance of shoulder flexors was moderately lower than the mean of references.

The patients showed different degrees of muscular exertion when performing the standardized load test (Table V), mean values being 92% and 95% of reference for men and women, respectively. Patients who used more than 100% of expected in MUR% (up to 133.5%, Table V) thus needed more muscular exertion than did reference individuals when performing the standardized load test.

Mean isokinetic knee extensor torque (Table VI), was slightly lower than reference means.

DISCUSSION

The outcome regarding return-to-work (RTW) rate (87%) was high in the present study of patients referred for vocational rehabilitation after burn injury. Comparison with other studies is difficult and must be done carefully, since the outcome is influenced by many factors, e.g. selection of patients and type of rehabilitation content; a few other outcome figures are presented. In a systematic review, a mean of 66% of patients returned to work following their burn injury (3), the severity of burn being the most significant barrier to RTW. In a 2-centre study, 66% of survivors had returned to work 6 months post-burn (1). A subset of that study shows a high figure for RTW: 80% 2 years post-burn. With awareness of the possible differences between the materials, it seems that the present figure of 87% is at the same level. In a study of barriers to work resumption by burn survivors treated at a regional burn outpatient clinic, two-thirds had returned to work within one year (2) and barriers then entailed pain, impaired mobility, neurological problems and psychiatric issues. For those returning to work later than 1 year, impaired mobility was the only statistically significant predictor of unemployment.

The social welfare system in Sweden supports adaptation of working conditions, altered work-stations, ergonomic devices, reduced working hours, or help to get a more suitable job. Also, if a patient can only return to part-time work the Social Insurance Agency usually makes up the economic difference for the remaining time.

It is reasonable that physical fitness facilitates RTW. Indeed, in the group that returned to work, a normal expected workload was achieved on the bicycle exercise test. It should be noted that those who returned to full-time work were approximately 10 years younger at the time of injury than those who returned to part-time jobs.

A systematic review based on over 50 articles summarizes and provides a guiding framework for the key processes and factors important for comprehensive vocational evaluation following burn injury (25).

Pulmonary function tests performed late after severe thermal injury or smoke inhalation indicate varying persistent lung-function impairments in some patients. These consist of obstructive and/or restrictive ventilatory defects, bronchial hyper-reactivity, scarring and impaired oxygen transfer. Patients subject to smoke inhalation, and patients developing acute respiratory distress syndrome (ARDS) are at most risk (26–29). It would appear, however, that many recover completely (29, 30).

The most sensitive test for impaired lung function in the present study was radio spirometry. A majority (70%) of the patients had slightly, but definitely, prolonged wash-out times for inhaled xenon (133Xe), consistent with air trapping in the peripheral airways. This was not so evident on standard spirometry. Ventilation scintigraphy has been used for decades to detect and quantify the degree of airway obstruction (31, 32). The advantage of this method is its ability to selectively detect ventilation impairment for different lungs and lung regions with high sensitivity, while standard pulmonary function tests provide only a sum-function at the mouth (33, 34).

The proportion of smokers (67%) was a significant confounder, especially since pre-hospital lung-function tests were not available.

Residual impaired oxygen transfer, expressed as DLCO below 80% of expected, was seen in 6 patients. The clinical relevance of this finding did not appear to be very important, considering that none of these patients desaturated in SpO_2 during the bicycle exercise test. The relatively good lung function in the present patients contrasts with some previous reports on PFTs in severe thermal injury (28, 31). Contributing reasons might be the development and use of more sophisticated ventilators and the support of skilled intensive-care specialists.

Many jobs require sufficient arm-hand function, and burn injuries to hands or arms limit the choice of jobs to which return is possible. Most of the present patients had injured extremities, yet most became able to manage their disability.

The ability to move the arm forwards-upwards and manage load is essential for many activities of daily living and in work situations. Shoulder-joint flexor muscle torque varied greatly, from extreme weakness to double or more of the reference mean. No specific studies have been found that use comparable measuring technique, precluding comparisons.

During the standardized shoulder-muscle-load test, the patients used, on average, slightly less of their muscle strength capacity (MUR%) than reference individuals from a population study (23, 24). Skin contractures around the shoulder joint can cause a moment of force opposed to that of force/torque caused by activation of the shoulder flexors (arm forwards-upwards lift). The present results indicate that possible contractures around the shoulder joint did not, on average, influence the degree of exertion needed, but this could partly explain some patients' need for more exertion to fulfil the task. This is shown in the large range of results compared with references.

Approximately one-third of the present burn-injury patients needed more of their muscular strength capacity for using their upper extremities in the load test. Using more of one's strength for a given task normally results in earlier muscular fatigue for that task. This supports our earlier observation (14) that some burn-injury patients reported muscular fatigue, despite appropriate exercise training. This would imply that the limitation of arm use due to fatigue depends on muscular function rather than cardio-pulmonary function.

Study limitations

A limitation of this study is the lack of a matched control group. The panorama of individual-specific injuries and the duration of this event-driven RTW study did not allow such a design. A further limitation is the lack of early post-injury functional data. Such data is either impossible or extremely difficult to obtain in the acute-trauma setting. A third limitation is some missing measurements during follow-up, a problem related to the injury itself, e.g. fragile skin and/or allodynia, and the complex nature of the rehabilitation process among burn patients.

Conclusion

A high rate of RTW can be achieved in a cohort of seriously compromised thermal injury patients following team-based, individualized, medical-vocational rehabilitation. The rehabilitation period may extend over a period of many years. Pronounced variations occur in muscular strength and endurance of extremities, from weak to powerful, where arm endurance is most affected. Pulmonary function in general appears to be restored. A dominating impairment is varying degrees of airway obstruction, disclosed by radio spirometry. Bicycle exercise performance would, on average, be within the normal range, except for a few cases.

The authors have no conflicts of interest to declare.

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