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RESEARCH PAPER

Clinical predictors of pulmonary functions, respiratory/peripheral muscle strength and exercise capacity at discharge in adults with burn injury

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ABSTRACT

Purpose: To identify clinical predictors of pulmonary functions, respiratory and peripheral muscle strength and functional exercise capacity in burn injury patients, and to compare these parameters with healthy subjects.

Methods: The study included 47 burn injury patients aged 20–49 years, and 47 age and gender-matched healthy subjects. The patients were evaluated on the day of discharge from hospital. Pulmonary functions and respiratory muscle strength were assessed with a spirometer (Cosmed Pony FX). Hand grip and pain were evaluated with a Jamar dynamometer and visual analog scale, respectively. The six-minute walk test (6-MWT) was performed to determine the functional exercise capacity of the participants.

Results: With the exception of FEV_1/FVC, all the parameters of pulmonary functions test, respiratory and peripheral muscle strength and 6-MWT distances were lower in the burn injury patients than in the healthy subjects ($p < 0.05$). Significant predictors for these parameters were age, gender, height, body mass index, total burn surface area, burn injury type, the presence of trunk burn, hand burn, lower limb burn, inhalation injury, and intubation in the burn group ($p < 0.05$).

Conclusions: Burn injury and the demographic characteristics of the patients are important determinants of clinical parameters. These results are clinically important as they can be of guidance in creating a personalized rehabilitation program.

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KEYWORDS
Pulmonary function; respiratory muscle strength; exercise capacity; burn injury; six-minute walk test

➤ IMPLICATIONS FOR REHABILITATION

- Burn patients have impaired pulmonary functions and exercise capacity at discharge. Assessment of respiratory muscle strength should be added into clinical practice in adults with burn injury.
- Lung functions and exercise capacity should be evaluated in burn patients at discharge.
- It is important to monitor lung functions of burn patients after discharge.

Introduction

Burns are catastrophic and traumatic injuries that can lead to impaired functional exercise capacity, compromised pulmonary function, decreased muscle strength/endurance, and limited daily living activities [1]. As the survival rate increases after burn injury, these complications and extensive physical impairments that negatively affect quality of life and health, are encountered in the chronic phase of injury beyond the acute period [2].

Changes in physiological and metabolic responses which occur immediately following burn injury and continue for up to 24 months can give rise to decreased exercise capacity and alterations in pulmonary functions, which may be impaired by the disruptions/changes in lung mechanics and alveolar capillary membrane and inspiratory/expiratory muscle weakness [3,4]. The long-lasting pathophysiological responses affect the patients adversely so may consequently reduce aerobic capacity and restrict mobility and functions in later periods [1,5].

There are a few studies in the literature evaluating pulmonary functions, aerobic capacity and physical outcomes in the acute or chronic period of burn injury [5–9]. Those studies have shown that patients with burn injury have disrupted pulmonary functions, and decreased functional exercise capacity, grip strength and physical activity [6–9]. In addition to those studies, Bourbeau et al. demonstrated that although pulmonary functions were impaired, exercise capacity did not change in adults with inhalation injury [10]. However, Willis et al. reported that burn patients with or without inhalation injury have reduced aerobic capacity at 2–7 years post-injury [11]. In a study of pediatric burns, it was emphasized that the time of evaluation of exercise capacity is a crucial factor for burn injury to demonstrate recovery [12]. There are also studies with contradictory results since the evaluation time of the exercise capacity/muscle strength of adults with burn injury has not been standardized [13,14]. Ganio et al. reported that burn injury adults with well-healed skin grafts had a low aerobic capacity even at approximately 16 years post-injury compared to non-burned subjects [13]. However, a long-term follow-up study of adult burn survivors showed that with the exception of a few patients, exercise capacity was observed to be normal

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despite impairments in pulmonary function test results and muscle strength/endurance [14]. Although studies regarding the impairment in lung functions and reduced skeletal muscle strength following burn injuries are well established [3,6,8–11,15], the evaluation of respiratory muscle strength is generally ignored. Another weak aspect of the studies in literature is that although it is known that pulmonary functions can be adversely affected in the acute period of injury [6], there has been insufficient research into the effect of possible influencing factors related to burn injury on respiratory muscle strength, pulmonary function and exercise capacity and the evaluation of these parameters together. Considering the importance of the time of the clinical measurements, which is an indicator of the recovery of burn patients, discharge from hospital is the start of an important period when these individuals return to their pre-burn injury life. Although patients have received standard burn treatments during hospitalization, the factors affecting lung functions and muscle strength and the differences in these parameters from matched healthy subjects are still unknown at discharge from hospital. Knowing the clinical determinants that influence these parameters will help clinicians to create an appropriate and personalized rehabilitation program following burn injury to prevent further complications affecting the patient's functions, mobility or activities of daily living, which may arise in the chronic period of injury.

Accordingly, the primary objective of this study was to determine the clinical factors affecting pulmonary functions, respiratory muscle, grip strength, and functional exercise capacity. The secondary aim of this study was to compare these parameters in adult patients with burn injury and healthy subjects.

Methods

Participants and study design

This case-control study included a total of 94 individuals aged 20–49 years, comprising 47 patients with burn injury, and 47 age and gender-matched healthy subjects. The burn injury patients included were those who were being followed up as inpatients. Patients with neurological deficit, neuromuscular diseases or severe cardiac problems were excluded from the study. The exclusion criteria for healthy participants were (i) having a respiratory, cardiac, or neurological disease that affected pulmonary functions or exercise capacity and (ii) doing regular sports (3–5 days per week) during the last 3 months. The reason for excluding healthy participants who performed regular sports was that the burn injury patients had not performed regular sports in the last 3 months prior to the burn injury. It was an important criterion for matching the patient and control groups that the habit of doing or not doing regular sports was similar. All the patients were evaluated on the day of discharge from hospital. All the patients received standard burn treatment, including standard medical care, wound care, physiotherapy, and mobilization program during hospitalization. All the participants were informed about the procedure of the study and those who consented to provided written informed consent and participate voluntarily were included in the study. Approval for the procedure of the present study was granted by the Institutional Research Ethics Committee.

Burn injury and clinical/demographic information assessment

Demographic and clinical information about the burn injury characteristics, including age, gender, height, weight, body mass index (BMI), cause of burn injury, burn localization, burn injury degree, and total burn surface area (TBSA) (TBSA *defined using the rule of nines*) were recorded. In addition, the presence of inhalation injury, intubation, co-morbidities, smoking status, length of hospital stay, duration of intubation, the number of patients who underwent surgery and number of operations were recorded for all patients.

Pulmonary function testing and respiratory muscle strength measurements

Pulmonary function tests and respiratory muscle strength were assessed using a portable spirometer (Cosmed Pony FX, Rome, Italy) in accordance with the American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines [16,17]. Forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, forced expiratory flow (FEF 25–75%), and peak expiratory flow (PEF) were obtained at the end of the pulmonary function test. The spirometer expresses the results of the pulmonary function test as liters or percentage of the predicted values adjusted by demographic variables (age, height, weight, and gender) [18]. Maximal inspiratory pressure and maximal expiratory pressure (MIP and MEP, respectively) were performed to determine respiratory muscle strength. The participants repeated the respiratory muscle strength test 3–5 times until there was at least <10% difference between the values, then the highest value was recorded for further analysis. The MIP/MEP values expressed as a cmH_2O were calculated according to age and gender [18,19].

Peripheral muscle strength and pain assessments

Grip strength was evaluated with a Jamar dynamometer (Baseline Hydraulic Hand Dynamometer, Irvington, NY) and pain severity with a visual analog scale (VAS) ranging from 0 (no pain) to 10 (extreme pain). The measurement of grip strength was performed on the dominant side. The average value of three measurements for grip strength was used for each participant. The predicted values of grip strength were calculated according to age and gender [20].

Functional exercise capacity evaluation

The six-minute walk test (6-MWT) was used to evaluate functional exercise capacity. The 6-MWT was performed in a 30-m corridor with standardized instructions according to the ATS guidelines [21]. The walking distance was recorded after the 6-MWT. The predicted values of 6-MWD were calculated according to age and gender [22,23].

Statistical analysis

Statistical analysis was performed using IBM SPSS 21.0 software (IBM SPSS Statistics, Armonk, NY). The results were presented as mean ± standard deviation, ratio or percentage. Histogram and normality tests (Kolmogorov–Smirnov, and Shapiro–Wilk) were used to detect conformity of the numeric variables to normal distribution. For the comparison of demographic and clinical parameters between the groups, Student's *t*-test or Mann–Whitney's *U* test was used, where appropriate. Spearman's or Pearson's correlation coefficient was used for univariate analysis between pulmonary function test, respiratory muscle strength, peripheral muscle strength, functional exercise capacity, and other clinical variables (burn injury, clinical and demographic data). Stepwise

Table 1. Burn injury characteristics.

Variables			Burn Group
Burn injury type	Electric, *n* (%)		14 (29.8)
	Flame, *n* (%)		16 (34)
	Scald, *n* (%)		17 (36.2)
Burn injury degree	1st and 2nd degree (superficial and deep), *n* (%)		10 (21.3)
	2nd degree (superficial and deep) and 3rd degree, *n* (%)		37 (78.7)
TBSA %			21.46 ± 10.33 (10–47)
Length of hospital stay (days)			52.17 ± 30.13 (17–126)
Presence of lower limb burn, *n* (%)			30 (63.8)
Presence of face burn, *n* (%)			16 (34.0)
Presence of hand burn, *n* (%)			33 (70.2)
Presence of trunk burn, *n* (%)			23 (48.9)
Presence of inhalation injury, *n* (%)			10 (21.3)
Presence of intubation, *n* (%)			6 (12.8)
Duration of intubation (days)			3.5 ± 1.04 (2–5)
Number of patients who underwent surgery, *n* (%)		Number of operations	
		0	10 (21.3)
		1	20 (42.6)
		2	6 (12.8)
		3	9 (19.1)
		4	2 (4.3)

TBSA: total burn surface area, values are presented as mean ± SD (min–max) or number of patients (percentage).

multiple linear regression analyses were used to identify factors predicting pulmonary function test, respiratory muscle strength, peripheral muscle strength, and functional exercise capacity. Significant parameters found in the univariate correlation analysis ($p < 0.20$) were entered into the multivariate analyses. A value of $p < 0.05$ was accepted as statistically significant.

Results

The burn injury characteristics in terms of type of injury, TBSA, length of hospital stay, duration of intubation, the percentage of burn localizations, the number of patients who underwent surgery, and number of operations are given in Table 1. The comparisons of clinical and demographic parameters between the groups are presented in Table 2. The groups were similar in respect of age, gender, height, weight, BMI, and the ratio of current smokers ($p > 0.05$). Comorbidities were determined in four patients with burn injury (two patients had asthma and two patients had diabetes mellitus).

The percentage of the predicted values of FEV_1, FVC, PEF, FEF25–75%, and the actual liters of FEV_1 and FVC, were significantly lower in the burn injury patients than in the healthy subjects ($p < 0.05$). FVC and FEV_1 <80% of the predicted values were determined in 19 patients. There were two healthy subjects determined with FVC results <80% of predicted, and three healthy subjects with FEV1 results <80% of predicted. The ratio of FEV_1/FVC was found to be similar between the groups ($p > 0.05$). In terms of respiratory and peripheral muscle strength, the patients with burn injury had lower values of MIP, MEP, and grip strength than those in the control group. The MEP values of all the burn patients and MIP values of 37 of the burn patients were determined to be <80% of the predicted values adjusted for age and gender. All the burn patients had low (<80% of the predicted values) grip strength. When the individual results of respiratory/peripheral muscle strength of the healthy control group were examined, MIP <80% of the predicted values was determined in 11 healthy subjects. The MEP values of all the healthy control group were <80% of the predicted values adjusted for age and gender. The grip strength results of 38 healthy subjects were found to be <80% of the predicted values. The walking distance of 6-MWT was significantly lower in patients with burn injury compared to the control group; five patients could not perform the 6-MWT due to amputation following burn injury. The 6-MWT distances of 32 burn patients and three healthy subjects were found to be <80% of the predicted values.

Table 2. Comparison of clinical and demographic parameters between the groups.

Characteristic	Burn group $n = 47$	Control group $n = 47$	p
Age (years)	31.44 ± 8.77	29.25 ± 7.02	0.256
Gender (F/M)	20/27	20/27	1.00
Height (cm)	168.91 ± 8.55	169.79 ± 9.17	0.635
Weight (kg)	71.21 ± 13.43	71.80 ± 9.97	0.808
BMI (m^2/kg)	24.87 ± 3.96	24.89 ± 2.83	0.815
Presence of smoke (%)	53.2	53.2	1.00
Presence of comorbidity (%)	10.6	0	0.022*
Pain	4.30 ± 1.78	–	
Pulmonary functions			
FVC %	82.61 ± 16.51	97.19 ± 10.39	<0.001*
FVC lt	3.38 ± 1.12	4.44 ± 1.01	<0.001*
FEV_1 %	81.61 ± 14.31	94.36 ± 11.30	<0.001*
FEV_1 lt	2.75 ± 0.92	3.67 ± 0.85	<0.001*
FEV_1 /FVC	81.17 ± 7.58	82.44 ± 6.14	0.372
PEF	62.08 ± 20.16	82.34 ± 15.06	<0.001*
$FEF_{25–75}$	77.76 ± 19.39	87.80 ± 6.13	0.001*
Respiratory muscle strength			
MIP cmH_2O	66.95 ± 15.47	93.12 ± 17.31	<0.001*
MEP cmH_2O	73.97 ± 19.31	102.87 ± 21.88	<0.001*
Peripheral muscle strength			
Hand grip strength (kg)	21.81 ± 8.24	40.48 ± 12.09	<0.001*
Functional exercise capacity			
6 MWT (m)	446.19 ± 120.43	711.35 ± 99.47	<0.001*

BMI: body mass index; MWT: minute walk test; FVC: forced vital capacity; FEV_1: forced expiratory volume; PEF: peak expiratory flow; $FEF_{25–75}$: forced expiratory flow; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; M: male; F: female.
*$p < 0.05$, values are presented as mean ± SD, percentage or ratio.

As a result of the multivariate analyses (Table 3), older age, male gender, high TBSA, increased BMI, short height and the presence of trunk, or hand burns and inhalation injury were significant predictors of pulmonary function test results. TBSA, the presence of inhalation injury, intubation and burn injury type (scald burn injury) and height were determined as significant predictors of respiratory muscle strength (MIP and MEP values). The presence of inhalation and hand burn injury and height were found to be significant predictors of grip strength while the presence of lower limb burn and inhalation injury and age were significant predictors of functional exercise capacity ($p < 0.05$).

Table 3. Significant predictors of pulmonary functions, respiratory and peripheral muscle strength and functional exercise capacity in the burn group.

Prediction		Variable	B	95% CI Lower bound	95% CI Upper bound	p	R^2
Pulmonary functions	FVC %	TBSA	−0.956	−1.310	−0.601	<0.001	0.469
		Gender[a]	9.750	2.417	17.084	0.01	
	FVC lt	Trunk burn[b]	−1.185	−1.675	−0.694	<0.001	0.49
		Age	−0.047	−0.075	−0.019	0.002	
	FEV_1 %	TBSA	−1.012	−1.296	−0.729	<0.001	0.535
	FEV_1 lt	TBSA	−0.041	−0.060	−0.022	<0.001	0.581
		Age	−0.037	−0.059	−0.016	0.001	
		Height	2.667	0.363	4.971	0.024	
	FEV_1/FVC	Inhalation injury[b]	−8.619	−13.200	−4.037	<0.001	0.337
		BMI	−0.787	−1.264	−0.309	0.002	
	PEF	TBSA	−1.012	−1.513	−0.511	<0.001	0.269
	$FEF_{25–75}$	TBSA	−0.712	−1.198	−0.226	0.005	0.351
		Hand burn[b]	−14.581	−25.447	−3.715	0.01	
Respiratory muscle strength	MIP	TBSA	−0.879	−1.306	−0.453	<0.001	0.608
		Height	79.203	36.701	121.706	0.001	
		Burn injury type	11.133	3.630	18.636	0.005	
		Intubation[b]	12.083	0.052	24.114	0.049	
	MEP	TBSA	−2.215	−2.886	−1.544	<0.001	0.589
		Inhalation injury[b]	26.981	10.202	43.761	0.002	
Peripheral muscle strength	Grip strength	Hand injury[b]	−9.439	−12.894	−5.985	<0.001	0.651
		Height	41.813	24.193	59.434	<0.001	
		Inhalation injury[b]	−5.753	−9.619	−1.886	0.004	
Functional exercise capacity	6 MWT	Lower limb burn[b]	−170.822	−207.358	−134.287	<0.001	0.824
		Inhalation injury[b]	−92.226	−139.274	−45.178	<0.001	
		Age	−2.508	−4.466	−0.550	0.013	

B: unstandardized coefficients; R^2: coefficient of determination; TBSA: total burn surface area; BMI: body mass index; MWT: minute walk test; FVC: forced vital capacity; FEV_1: forced expiratory volume; PEF: peak expiratory flow; $FEF_{25–75}$: forced expiratory flow; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; MWT: minute walk test.
[a]Male vs. female.
[b]Having vs. not having.

Discussion

The aim of the present study was to identify the clinical predictors which may affect pulmonary functions, respiratory muscle strength and functional exercise capacity and to compare these parameters between adult patients with burn injury and healthy subjects. With the exception of FEV_1/FVC ratio, pulmonary functions (FEV_1, FVC, PEF, FEF25–75%), respiratory muscle strength (MIP and MEP values), grip strength and the walking distance of 6-MWT were found to be significantly lower in the burn group compared to the control group. The findings of the present study showed that burn injury had a negative effect on these parameters, except for FEV_1/FVC ratio. It was also demonstrated that pulmonary functions were adversely affected by male gender, older age, high TBSA, increased BMI, short height and the presence of trunk, or hand burns and inhalation injury. In addition, it was observed that TBSA was negatively correlated with MIP and MEP values, while the presence of inhalation injury, intubation and scald burn injury and height had a positive effect on these parameters. Moreover, the presence of hand and inhalation burn injury and height were observed to have a negative effect on grip strength while the presence of lower limb burn and inhalation injury and age had an adverse influence on the functional exercise capacity. To the best of our knowledge, this is the first report showing the clinical determinants affecting pulmonary functions, peripheral/respiratory muscle strength and functional exercise capacity in burn injury patients.

The findings of the present study were consistent with those of recent studies that have demonstrated impairments in pulmonary functions and decreasing exercise capacity in burn injury adults [1,6,7,9,11]. Although there was no difference in the ratio of FEV_1/FVC between the burn injury patients and healthy individuals in the current study, 19 burn injury patients had compromised pulmonary functions with restrictive disease pattern (lower limits of 80% predicted FVC and FEV_1; normal FEV_1/FVC ratio). In the control group, with the exception of a few cases, the pulmonary function test results of the healthy subjects were normal.

It has been shown that compromised pulmonary functions in burn injury patients initially appear as an obstructive disease pattern and may last for up to two years after the injury [24]. This obstructive disease pattern then develops into a restrictive disease pattern with recovery taking a longer time [8]. However, Morris and Spitzer [25] evaluated pulmonary functions in 27 adult burn patients at different times that were not standardized (11–149 days) following injury and reported that patients had normal pulmonary functions despite a severe burn injury. Although the TBSA was similar in the present study and in the study by Morris and Spitzer (10–47% vs. 5–52%) [25], the evaluation time in the present study was standardized as the day of discharge from the hospital. The results of the current study are in agreement with the study of Suman et al. [2] suggesting that burn patients have a mild restrictive disease pattern which is characterized by low FEV_1 and FVC and normal FEV_1/FVC.

When the predictors of pulmonary functions were examined, the findings of the present study confirmed that the presence of inhalation and TBSA were important clinical determinants. This was also stated in the study by Whitener et al. [6], where the incidence of respiratory complications following thermal injury was associated with the severity of burn injury, and the presence of smoke inhalation, which leads to significant impairments in pulmonary function in the acute term of the injury [6,26]. It has been reported that combined burn and inhalation injury has an adverse effect on pulmonary functions compared to either of these alone [6]. This combination leads to restrictions in lung volumes and the effect of burn surface area on pulmonary functions is greater than inhalation damage in patients with combined injury [6]. The presence of trunk burn injury was also found to be associated with a decrease in FVC (lt), which was an indicator of restrictive pattern in the present study. The percentage of chest burn has been shown to have an adverse effect on spirometric parameters in the initial period of injury, and subsequent contractures of the chest wall may cause a restrictive disease pattern in the pulmonary function test [6,27]. In addition, pulmonary functions were seen to be influenced by age, gender, BMI, height, and the presence of hand burn injury in this study. It has been shown in previous studies that increasing age, BMI, short height, and female gender have an adverse effect on pulmonary functions [28–30]. However, FVC% was negatively affected by male gender in the present study, which could have been due to the fact that the majority of patients with inhalation injury were male. Moreover, FEF 25–75% was influenced by the presence of hand burn injury. The TBSA of with and without hand burn injury was found to be $23 \pm 11\%$ vs. $16 \pm 4\%$ ($p = 0.003$). FEF25–75% may have been indirectly affected by the higher percentage of TBSA in burn patients with hand injury.

When the respiratory muscle strength values were analyzed, the inspiratory muscle strength of the majority of patients and the expiratory muscle strength of all patients was lower than the predicted values, indicating that these individuals had severe respiratory muscle strength weakness. Surprisingly, the expiratory muscle strength of all the healthy subjects and the inspiratory muscle strength of 11 healthy individuals were found to be below the predicted values. It is known that physically trained individuals have increased respiratory muscle strength/endurance compared to sedentary subjects [31]. This weakness in respiratory muscle strength in the healthy subjects may be due to the fact that the individuals included as the control group had not undertaken regular exercise in the last three months. Although the respiratory muscle strength of burn patients has not been evaluated to date, the current results demonstrating weakness in inspiratory/expiratory muscles are consistent with the findings of previous studies showing skeletal muscle weakness in burn injury patients [15,32,33].

Just as for pulmonary functions, respiratory muscle strength was adversely affected by high TBSA and short height in the present study. In addition, scald burn injury type had a more positive effect on inspiratory muscle strength than electrical or flame burn injuries. All the patients with inhalation injury had flame burns and four patients with amputations that may have resulted in prolonged immobilization had electrical burns, which may have had a negative effect on inspiratory muscle strength in these burn types compared to scald burns. An unexpected result of the present study was that the inspiratory and expiratory muscle strength of the patients was positively affected by the presence of intubation and inhalation injury, respectively. It can be considered that the low number of patients with inhalation injury and intubation may have caused this unexpected result.

Similar to the results for respiratory muscle strength, all of the burn patients and 38 healthy individuals had low grip strength (<80% of the predicted values). It is known that pulmonary function tests and respiratory muscle strength (MIP and MEP values) are associated with peripheral muscle (hand grip) strength [30]. In this study, the lack of regular exercise in the healthy individuals may have adversely affected peripheral muscle strength as well as the respiratory muscles. Grip strength, which is an indicator of functional recovery and upper extremity strength [9], was seen to be adversely affected by the presence of hand burn and inhalation injury while it was positively influenced by greater height in the present study. These findings are consistent with those of previous studies which have shown that the presence of hand burn injury impairs grip/upper limb strength and height is an important predictor of grip strength [9,34,35]. Jarrett et al. [9] reported that the grip strength of burn patients with an upper limb injury on discharge was different from that of healthy subjects and these patients regained the normal values of grip strength over the 6 months following burn injury.

When the individual functional exercise capacity results were examined, 32 burn patients had reduced aerobic capacity. With the exception of three cases, almost all of the healthy individuals had normal exercise capacity. The results of the present study regarding impairments in the functional exercise capacity are consistent with those of many studies in showing that aerobic capacity is affected in the acute and chronic term of injury whether patients have a major burn or not [7,9,11]. Recent studies related to the exercise capacity of adult burn survivors have shown conflicting results. Ganio et al. demonstrated that burn patients had reduced aerobic capacity compared with healthy subjects even many years after the burn injury [13]. However, Björnhagen et al. reported that almost all the adult burn patients had a normal exercise capacity level. In the present study, the majority of the burn patients had reduced exercise capacity [14]. Compared to those previous long-term follow-up studies, individual results may have been negatively affected since the evaluations were performed only on the day of discharge in the present study. Although the clinical factors affecting exercise capacity have not been investigated to date, the results of a few studies evaluating the effects of inhalation injury on aerobic capacity are not consistent [5,10,11,24]. Those studies have reported that burn injury children with inhalation injury had similar endurance levels as children without inhalation injury and long-term exercise capacity was not impaired following inhalation injury in burn injury adults [10,24]. However, the presence of inhalation injury was determined to be a clinical predictor of exercise capacity in this study. This finding partially supports the results of Stockton et al. [5], who showed that patients with inhalation injury had pulmonary limitations in the exercise test.

Increasing age, which is known to have an adverse effect on exercise capacity [36], and the presence of lower limb burn injury were other factors affecting the 6-MWT in the current study. Significant impairments in mobility levels, walking ability, reduced lower extremity muscle strength and functional mobility are now recognized as potential complications following lower limb burn injury [37]. The adverse effect of the presence of a lower limb burn injury on functional capacity may have resulted from these complications as they may affect the exercise capacity. To prevent the adverse effects of these complications on exercise capacity, burn patients should be followed-up regularly after discharge and included as a long-term supervised or home-based rehabilitation program.

One of the limitations of this study could be said to that only burn injury patients who were being followed up as inpatients were included. When the long period needed for recovery of pulmonary functions and exercise capacity is taken into consideration, the lack of long-term follow-up of these patients constitutes another limitation of the present study. Future studies should investigate the clinical factors affecting these parameters in both outpatients and inpatients with long-term follow-up.

Implications for clinical practice

The present study demonstrated that adult patients with burn injury have impaired lung functions and reduced respiratory/

peripheral muscle strength and exercise capacity on discharge from hospital compared with matched healthy subjects. When the individual results were analyzed, these parameters in the majority of burn patients were found to be <80% of the predicted values. This is important clinical data showing that burn treatment, medical care, wound care, and individualized rehabilitation programs including respiratory/peripheral muscle endurance and strengthening programs should be continued with long-term follow-up programs after discharge to restore pulmonary functions, muscle strength and exercise capacity. When creating a structured, long-term rehabilitation program, the effects of the TBSA, age, gender, burn localization, burn injury type, and the presence of inhalation injury on lung functions and exercise capacity on discharge from hospital should be considered to be able to prevent further complications and to improve these parameters in adult burn injuries.

Conclusions

The results of this study showed the clinical predictors of pulmonary functions, respiratory/peripheral muscle strength, and functional exercise capacity in burn injury patients. These results can be considered clinically important as the respiratory muscle strength was also evaluated and this provides a strong rationale for the early design of a personalized rehabilitation program and the inclusion of inspiratory/expiratory muscle strength training in such a program.

Disclosure statement

The authors declare no conflicts of interest.

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