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Original Article

LONG-TERM ASSESSMENT OF ECCENTRIC, ISOMETRIC, CONCENTRIC MUSCLE STRENGTH AND FUNCTIONAL CAPACITY AFTER SEVERELY BURNED ADULT

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ABSTRACT

Background: Severe burn leads to marked and prolonged skeletal muscle catabolism and weakness.

Objective: The aim of this study was to investigate the long term effect of severe burn injury on eccentric, concentric, isometric muscle torque, average power, lean body mass, six minute walk and 8-foot walk.

Design: Eccentric, isometric and concentric muscle torque and average power were assessed at 24 months in burned adult with 40%-50% total body surface area (TBSA) at 150 °/s by using isokinetic dynamometry, Total lean body mass (TLBM) and lower limb mass (LLM) measurements were assessed for both groups using dual energy X-ray absorptiometry. Functional capacity was assessed using six minute walk test (6MWT) and 8-Feet walk test. Lean body mass (LBM) was determined via dual energy X-ray absorptiometry. Nonburned adult was assessed similarly, and served as controls.

Results: Severely burned adult (n=35), relative to nonburned adult (n=42) had significantly lower peak torque of eccentric, isometric, concentric muscle strength, average power and functional capacity. The most affected type of muscle strength after burn was concentric, isometric then eccentric.

Conclusions: Our results serve as an objective data for assessing the three modes of muscle strength and functional capacity in severely burned adult population.

KEY WORDS: Burned Adult, Muscle Strength Assessment, Functional Capacity.

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INTRODUCTION

Burn trauma leads to damage of muscle, nerves, vascular, dermal and epidermal tissue with subsequent pain; also burns result in severe psychological and emotional distress because of long-term hospitalization, scarring and deformity [1]. Low physical work capacity and muscle strength are major obstacles in allowing the burn victim to perform activities of daily living [2].

Burn injury is associated with functional, metabolic, and pharmacological aberrations [3]. The functional change in skeletal muscle during and after critical illness is weakness or decreased tension-generating capacity [3,4].

Skeletal muscle weakness after thermal injuries causes hypoventilation and dependence on respirators, a condition that increases morbidity and mortality. Severe burns with total body surface area (TBSA) more than 30% leads to weaker muscle tonus even years after the trauma, suggesting either an inability to fully recover or an insufficient rehabilitation [5].

Morphological changes following thermal injuries in muscles include mitochondrial alterations, increase in cortisol and catecholamines which exerts a catabolic effect that depends upon the percentage of TBSA involved [6], increased metabolic rate can persist until wound closure is achieved and perhaps for 6 to 9 months after wound closure [7].

Muscle strength measurement is a diagnostic procedure commonly performed in the assessment of patients with presumed neurological deficits and for rehabilitation outcomes [8]. Also; Assessment of functional capacity reflects the ability to perform activities of daily living that require sustained aerobic metabolism and provides important diagnostic and prognostic information in a wide variety of clinical and research settings [9].

Assessment of eccentric, concentric and isometric muscle torque and functional capacity can be useful information in evaluating muscle strength in severely burned adults and the efficacy of choosing the suitable rehabilitation strategies used for the rehabilitation program. Therefore, in this study, isokinetic quadriceps eccentric, isometric, concentric muscle torque data, average power, lean body mass and functional capacity in burned adult and age matched controls is presented for clinical application and rehabilitation of burned populations.

METERIALS AND METHODS

Subjects: A 35 burned adults their ages 25-40 years were participating in this study. The groups consisted of an adult with burn injury and normal healthy adult to serve as age matched controls and was randomly selected to match the burned group in their age, weight, height, body mass index (BMI) and percent body fat (% BF) was estimated from four skinfolds using a Harpenden skinfold caliper (British indicators, UK), each skinfold site was assessed a minimum of two times. **Inclusion criteria**: Only burned subjects with total body surface area (TBSA) ranged from 40%-50% assessed by the ''rule of nines'' method during excisional surgery in the acute phase injury and not included in any specific exercise program were enrolled. All patients receive the same physical therapy program during the hospitalization period and outpatients. **Exclusion criteria**: Includes diabetes, sepsis, neuromuscular disease, leg amputation, balance disturbance, anoxic brain injury, psychological disorders, quadriplegia, or severe behavior or cognitive disorders. All of the burned subjects received ''standard'' medical care and treatment from the time of admission and acute care of the burn until time of discharge. This standard medical care refers to the typical and reasonable surgical and medical care during the acute phase, as well as after discharge from the acute unit. A written informed consent form giving agreement to participation and publication of the results was signed by the participants and the study was approved by the departmental council.

Assessment of eccentric, concentric and isometric muscle torque: Eccentric, concentric and isometric muscle torque was assessed at 3 months after the date of burn injury by using a Biodex Isokinetic Dynamometer (Biodex Medical System, Shirley, NY, USA). The isokinetic test for eccentric and concentric torque was performed on the dominant leg extensors and tested at an angular velocity of 150 °/s and the isometric torque at 0°/s. The participants were seated and their position stabilized with a restrained strap over the mid-thigh, pelvis, trunk and chest in accordance to the Biodex Advantage Operating Manual, each participant was instructed to fold their arms across the chest for each contraction to minimize any contribution of the upper body. All participants were familiarized with the Biodex test in a similar manner. First, the procedure was demonstrated by the administrator of the test. Second, the test procedure was explained to the participants, and third, the participants were allowed to warm-up and practice the actual movement by performing three repetitions without a load. More repetitions were not allowed to prevent the potential onset of fatigue. The anatomical axis of the knee joint were aligned with the mechanical axis of the dynamometer before the test. After the three sub maximal warm-up repetitions, 10 maximal voluntary muscle contractions (full extension and flexion) were performed. The maximal repetitions were performed consecutively without rest in between. Three minutes of rest were given to minimize the effects of fatigue and the test was repeated. Values of peak torque were calculated by the Biodex software system. The highest peak torque (expressed as Newton-meters N.m) between the two trials were selected. Verbal encouragement was given during the test. The biodex dynamometer was calibrated prior to testing, using known masses placed on the lever arm.

Functional capacity assessment: The Six-Minute walk test (6MWT) is a practical simple test without exercise equipment. It is easy to administer, better tolerated, and more reflective activities of daily living than the other walk tests" [10]. The participants were asked to walk around a series of traffic cones, which were placed to mark off a circular walking area of about 40 feet in diameter that was measured before the test. Subjects were instructed to attempt to walk for 6 minutes, covering as much ground as possible in a work effort that allowed the person to talk without becoming short of breath. The tester walked alongside the subject, and timed the walk with a stop watch. Subjects were not prompted by the tester because previous studies have found that encouragement provided by the tester affects performance, with patients receiving encouragement walking greater distances than those who do not ($p < .02$) [11]. A counter was used to count the number of laps completed by the subject. After 6 minutes, the subject was instructed to stop walking, a marker was placed on the ground, and the distance walked during the last lap was measured by a rolling tape measure. The total distance was derived by multiplying the number of laps by the circumference of the walking circle, and adding the distance covered on the last lap.

8-Foot walk test: Gait speed was measured by having the subject walk a distance of 8 feet. An S-foot walking line was marked off with an additional 2 feet at either end. Each subject was instructed to walk along the line at their usual speed and timed for 2 trials. Scoring was the number of seconds required to walk 8 feet divides the number of seconds into quintiles, with those people who are unable to perform the test receiving a zero. Since all our subjects were able to perform the test, the number of seconds was used as a continuous measure and the average of the 2 trials was used in the analysis.

Lean body mass: Total lean body mass (TLBM) and lower limb mass (LLM) measurements were assessed for both groups using dual energy X-ray absorptiometry (DEXA: Lunar Prodigy Vision, GE Medical Systems, Madison, WI). Prior to testing, the DEXA was calibrated according to the manufactures guidelines. During testing, participants were required to lay supine on the scanning table while their body was scanned. These measurements are then compared with standard models of thickness used for bone and soft tissue. Subsequently, the calculated soft tissue is separated into .The DEXA scan was used to determine total body composition, i.e., fat mass, lean mass whether it is TLBM or LLM is reported in kilograms and body fat percentage.

Data Analysis: All data were examined using SPSS version 16.0. Descriptive statistics used to compare demographic characteristics of all groups. The data were collected and statistically analyzed using unpaired t-test for each evaluation. Results are reported as means and standard deviations. For all procedures, significance was accepted at the alpha level of 0.05.

RESULTS AND TABLES

Seventy-seven adult were enrolled in the study (57 males, 20 females). Thirty-five adult with lower limb burn injury were tested 3 months after burn and compared to forty-two adult without burn, who served as matched controls. There were no differences at 3 months after burn between the groups in terms of age, height, standing weight, body mass index and body fat % (Table 1).

Table 1: Demographic characteristics of burned and nonburned control.

	Burned (N=35)	Nonburned (N=42)
Gender	27 male/ 8 female	30 male / 12 female
Body fat (%)	20.5±4.3/25.6±3.7	22.2±3.8 / 27.5±3.5
Age (years)	34.77±3.86	35.16±3.76
Height (m^2)	1.76±4.03	1.78±2.93
Weight (kg)	73.75±3.67	76.75±3.65
BMI (Weight kg / Height m^2)	23.8	24.22
TBSA	45.68±3.47	N/A
Average % TBSA of lower extremity	27.80±5.03	N/A
Average length of hospitalization	39.25±4.02	N/A
Average time since injury (months)	24.45±2.66	N/A

There were no significant differences between burned patients and nonburned control.

Table 2: Values of quadriceps torque, Average power, 6MWT, 8-feet Walk and TLBM for burned patients and non-burned control.

Mean values of quadriceps torque (Nm), Average power (watts), 6MWT (m), 8-feet Walk (Sec) and LBM			
(Mean ± SD)	Burned (N=35)	Nonburned (N=42)	P value
Eccentric ($0^{\circ}.s^{-1}$)	90.70±16.33	120.40±20.50	(p<0.0001) 0.0882*
Isometric ($150^{\circ}.s^{-1}$)	74.50±20.40	98.70±17.55	(p<0.0001) 0.1777*
Concentric ($150^{\circ}.s^{-1}$)	62.80±16.90	95.70±12.60	(p<0.0001) 0.5041*
Average power (watts)	55.75±18.22	75.40±21.80	(p<0.0001) 0.1429*
6 MWT (m)	344±17	590±13	(p<0.0001) 0.0506*
8-feet walk (second)	4.30±0.23	2.8±0.38	(p<0.0001) 0.0017*
TLBM (kg)	48.7±4.5	58.8±5.35	(p<0.0001) 0.1516*
LLM (kg)	6.9	8.5	
Fat mass (kg)	20.51±8.27	24.76±7.48	(p<0.0001) 0.2677*
Body fat %	25.57±7.55	29.13±6.68	(p<0.0001) 0.2255*

Values are mean±SD Newton-meters: Nm. *Significant

Eccentric, concentric and isometric muscle torque: Peak torque values of eccentric, isometric and concentric for non-burned adult were 120.40 NM, 98.70 NM and 95.70 Nm respectively. In burned adult, peak torque values of eccentric, isometric and concentric was 90.70 Nm, 74.50 Nm and 62.80Nm (Table 2). There was a significant difference in the amount of peak torque that could be generated in the three mode of muscle strength between the burn and non-burned groups. The non-burned group had a 24.50%, 32.48%, 52.38% greater peak torque for eccentric, isometric and concentric muscle strength (Fig. 1).

The greatest decrease in peak torque in burned adults was in concentric, isometric and eccentric respectively.

The average power value of the non - burned adult was 75.40 watts. In burned adult, average power was 55.75 watts. A significant difference was found in the amount of average power generated between the burned and nonburned groups. The nonburned group had a 35.24% greater average power.

Fig. 1: Mean values of quadriceps eccentric, isometric and concentric torque and power for burned patients and non-burned healthy control.

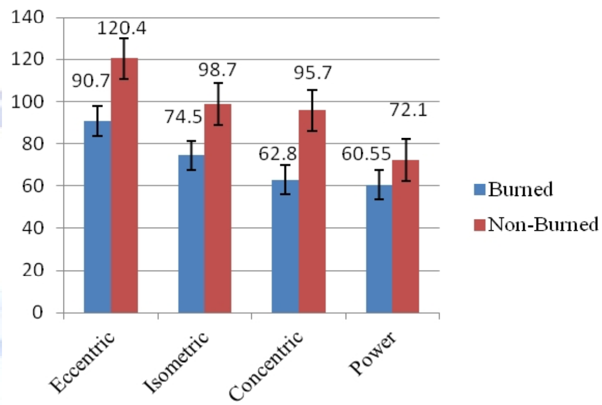


Fig. 2: Mean values of 6MWT and 8-Foot walk test for burned patients and non-burned healthy control.

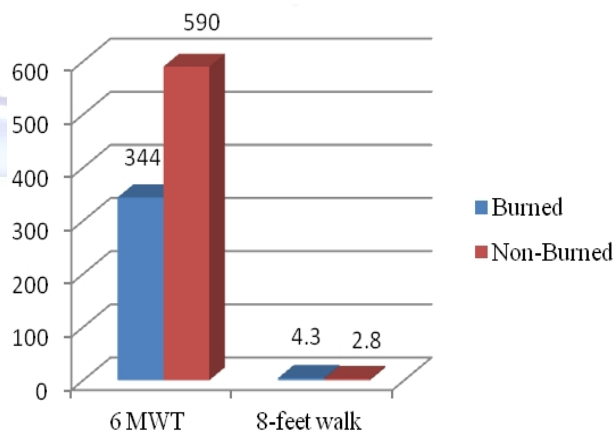
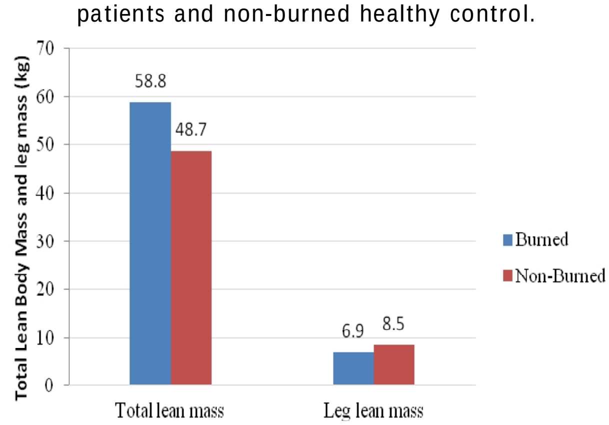


Fig. 3: Mean values of TLBM and LLM for burned patients and non-burned healthy control.



Lean body mass: Measurement of total and leg lean mass obtained by DEXA revealed significant differences between the two groups. For nonburned group, absolute values in TLBM were 58.8 kg and 8.5 kg for LLM. In contrast, TLBM and LLM in the burned group were 48.7 kg and 6.9 kg, respectively (Table 2). This reflected a 20.73% and 23.18% difference between the groups in mean TLBM and LLM, respectively (Figure 3).

Functional capacity: The average value of 6MWT for burning patients and none burned group was 344 meter and 590 meters respectively (Table 2). There was a significant difference in the distance obtained between the burn and non-burned groups; also the value of 8-Foot walk test for burned patients and nonburned group was 2.8 second and 4.30 second (Fig. 2). There was a significant difference in the time needed for the test between the burned and non-burned groups.

DISCUSSION

The main findings of our study were that persistent muscle weakness was reported in adult burned patients with more than 35% TBSA as compared to normal healthy age-matched subjects after 24 months post-burn in the three modes of muscle contraction (eccentric, isometric and concentric); also there was a decrease in average power, TLBM and functional capacity. Our results indicate a significant difference in the peak torque, average power, TLBM, 6MWT and 8-Foot walk between burned and nonburned adults. The loss of skeletal muscle results in a decrease in the three modes of muscle strength at 3 months after burn mainly in concentric, isometric and eccentric modes with decrease average power and functional capacity of the burned adult. The present study's findings were of importance in the field of burn to a variety of applications, including exercise training, physical therapy and rehabilitation after burn injury.

To our knowledge, there were no published reports that have studied the effects of the burn injury on the three modes of muscle contraction, TLBM and functional capacity in adult burned subjects with TBSA > 35% after 24 months post burn. Studies conducted by Hart et al. [12], St-Pierre et al 1998 [5], and Alloju et al. [13] demonstrated significant muscular weakness in patients with severe burn with TBSA > 35% and our results were consistent with these findings and indicate that burn injury affect the three modes of muscle contraction, TLBM and functional capacity. Post burn, muscle protein is degraded much faster than it is synthesized, increased cardiac work, increased myocardial oxygen consumption, severe lipolysis, severe muscle catabolism and insulin resistance; also the net protein loss leads to loss of lean body mass and severe muscle wasting leading to decreased strength and failure fully to rehabilitate [12].

Muscle deconditioning after major burn injury is due to bed rest and catabolic processes that lead to muscle atrophy [14], increased skeletal muscle catabolism, which can lead to a loss of lean body mass, decreased aerobic capacity and decreased functional ability [15].The Current strategies for burn rehabilitation were to assist an individual in achieving optimal function and independence, with the ultimate goal being community reintegration [16].

Most of burned patients subjected to bed rest after burn injury. Periods of limb unloading, produced by bed rest have been shown to induce muscle atrophy and loss of force and power this attributed to a selective decline in myofibrillar protein [17].Trappe et al. [18] conclude that 84 days of bed rest caused a 17% decrease in knee extensor muscle size and 40% loss in various functional tests.

Muscle wasting, which is the unintentional loss of 5% to 10% of total body muscle mass, occurs when there is an imbalance of muscle protein degradation and synthesis [6]. Protein degradation persists up to 9 months post–severe burn injury resulting in significant negative whole-body catabolism [12,19]. It is directly related to increases in metabolic rate [12]. Severely burned patients have a daily nitrogen loss of 20 to 25 g/m^2 of burned skin [19].

Muscle function assessment has not been well documented in the burn literature and most of the studies are limited by fewer numbers of patients and are often not directly compared to a nonburned group [2].

Assessment of muscle strength is a vital component of diagnosing and treating patients in which muscle weakness is present [8]. A variety of methods has been used to test quadriceps strength, isokinetic testing offers the benefit of objective measurement, primarily because it provides an objective means of quantifying existing levels of muscular strength [20].

Previous studies conducted to evaluate muscle function had some limitations. Roberts et al. [21] measure static grip strength and found that at discharge, isometric strength was significantly less than normal for age and gender and the study also contained a very small number of patients. In our study the isokinetic dynamometer was used to measure the eccentric, isometric, concentric mode of muscle strength and average power with a determined velocity and range.

The average time for assessment post burn injury in the current study was 24.45 months compared with an average of 3.14 years in the study by St-Pierre et al.[5], who conclude there was difference between burned and nonburned groups at base line assessment, and average time of 6.56 years in the study by Grisbrook et al.[22], who stated that, there was no differences between burned and nonburned groups prior to exercise training, which greatly influence the findings and this may suggest that muscle strength begins to recover from 3 to 6 years post burn injury, however this needs further investigation.

Most physical activities are more dynamic and rhythmic in nature so we used isokinetic testing to assess muscle function. Isokinetic testing has been reported to improve assessment of muscle function and allows measurement of dynamic muscular parameters under a predetermined rate. The rate chosen in our study was 150 ^{o}/s which closely approximates the motion of walking of burned patients and the fact that rehabilitation programs heavily focus on helping the patient return to normal level where they can resume activities such as walking and playing, which are largely dynamic muscular functions. Almekinders and Oman [23] stated in a review of isokinetic dynamometry, that this form of testing produced reliable data when testing simple uniaxial joints, such as the knee [23]. In addition, they reported that the strength of isokinetic testing was not in the diagnosis of orthopedic abnormalities, but instead in the monitoring of a patient's progress as they recover or participate in a rehabilitation program.

Isokinetic testing does have periods of accelerations and decelerations, even though a constant force throughout the functional range of motion is being exerted. Nonetheless, the final results in peak torque and total work can be reproduced consistently with each subject despite the accelerations and decelerations [24].

Eccentric and concentric actions provide a different stimulus to the muscle and, therefore, could produce different adaptations. Eccentric actions are characterized by a broader and faster cortical activity as movements are being executed, faster neural adaptations secondary to resistance training [25]. From a mechanical perspective, muscles are capable of achieving higher absolute forces when contracting eccentrically as compared with concentrically [26].

Eccentric isokinetic testing had a greater force production compared with concentric contraction at the same velocity. This can be explained by the contribution of the noncontractile elements of the muscle-tendon unit to force generation under eccentric conditions [27]. So the greater force production in eccentric mode may lead to saving the eccentric peak torque after burn injury more than isometric and concentric mode which was explained by our study but this may be changed if the three modes of muscle contraction were assessed after long time after the onset of burn. Most of studies conducted for rehabilitation of burned patients was using concentric rehabilitation program [2,22,28], this explain the severe deterioration of this mode after burn injury. Eccentric contractions produce higher muscular forces compared with concentric contractions and eccentric contractions produce less fatigue and are more efficient at metabolic level compared with concentric contractions [29].

The Physiological insults that occur as a result of thermal injury may limit the patient's aerobic capacity [30]. Previous research investigating limitations of the endurance capabilities of pediatric burn survivors is inconclusive [30,31].

There was limited literature available in reference to exercise tolerance in the adult burns population [32], but one report suggests that children with burns were limited in terms of exercise endurance [30]. While another reports no effect of the burn injury on exercise tolerance in children [31], our result indicate that there was decrease in patients functional capacity as compared to nonburned.

Cardiopulmonary complications resulting from burn and smoke inhalation injury can limit the body's ability to meet the energy needs required during exercise, which can further contribute to decreased aerobic capacity [31] and reduced participation in physical activity and consequent decrease in functional capacity.

Combination between bed rest, catabolism with sustained loss of muscle mass, as well as loss of muscle strength and decrease aerobic capacity after burn injury delays the return to customary pre-injury activities after severe burn. Xiaowu et al. [33] suggests that muscle disuse is the dominant cause of long-term muscle catabolism in burned patients.

There was a lack of information in the burn literature about assessment of muscle function by an objective and reliable methods in burned adults; also there were limited studies concerning the functional capacity assessment. We thought our study results share in documenting data in this area; in addition, it has potential clinical importance in the field of physical therapy and exercise specialists to use this information to evaluate and compare the muscle function and functional capacity of burned patient to other burned and nonburned individuals and in planning the rehabilitation protocol. More research in the area of burned patient assessment should be conducted because it was needed to elongate the data about muscle strength assessment, this paper may serve as a tool to fulfill this need.

There were some limitations to our study, the study conducted on small sample size; another limitation is the assessment of functional capacity at the same session of muscle strength assessment. In spite of having those limitations, we believe that this study served as a good report for assessment of muscle function and functional capacity in burned populations. Finally, our results demonstrate that sever burn affects the three modes of muscle contraction, average power, TLBM and functional capacity (6MWT and 8 feet walk test), and this result of important for rehabilitation of burned populations.

CONCLUSION

The results of our study have potential clinical significance and application in rehabilitation of burned adults; also it helps in planning the rehabilitation program for muscle strength after adult burns.

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