Adjunctive Effect of Light Emitting Diode on Hand Grip Strength in Burn Patients

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Abstract

Background: Improvement of hand grip strength is a crucial part of hand burn rehabilitation as it is one of the main reflectors of hand function, which in turn reflects general muscle strength.

Purpose: To assess the effect of using a Light Emitting Diode (LED) prior to hand grip strengthening exercises.

Methodology: Sixty male participants with hand burns were enrolled and randomized into two groups equal in number. Group (A) was exposed to LED for 20 minutes prior to performing hand strengthening exercises in addition to the traditional physical therapy treatment. Group (B) only received traditional physical therapy. Treatment sessions were conducted every other day for a study duration of six weeks. A Standard goniometer and hand grip dynamometer were used to measure Total active motion (TAM) and hand grip strength (HGS) respectively.

Results: Both groups showed significant improvements in the measured outcomes. However, there was a significant difference in the mean values of HGS in group (A) compared to that of group (B).

Conclusion: LED is a safe and effective modality for improving hand grip strength in 2nd-degree burn victims when applied before hand exercise.

Keywords: Hand burn, light emitting diode, grip strength, total range of motion, hand function.

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INTRODUCTION: Hand burn is common involved in victims with severe burns. In North America, more than 50% of burn injuries occur on the hands and upper extremities **(1)**. It is regarded as the primary contributor to functional impairment after a burn, especially when associated with larger burns **(2)**.

Hand burn can lead to a significant decrease in grip strength due to muscle mass loss, edoema, pain, and immobilisation; this loss will have a great impact on the overall functionality of the hand **(3).**

Hand function directly impacts quality of life (QoL) in patients with hand burns. It is also considered a potent predictor of reintegration into society and the workplace. The involvement of hands delays returns to normal activities, including work, which places more burden on employers while decreasing the employee's chances of successfully returning to work. As a result, hand burn rehabilitation tends to prioritise regaining optimal hand function **(4)**.

Even though a hand burn contributes to a small percentage of the total body surface area (%TBSA), hand treatment is considered very challenging when it comes to rehabilitation due to the hands' anatomical complexity and their significance in everyday activities **(5)**.

Hand rehabilitation is a crucial component of effective burn treatment since it aims to maintain function, prevent the development of deformities, and restore damaged functions. **(6)**

Several techniques are used for hand rehabilitation. Including positioning and splinting, exercise and manual therapy, desensitisation therapy, functional rehabilitation, and hand reeducation to restore and improve the fine motor skills of the hand. Inadequate or late rehabilitation can lead to unfavourable outcomes **(7)**.

Improvement of hand grip strength is a crucial part of hand burn rehabilitation; it reflects improvement of overall hand function, which in turn reflects general muscle strength **(8)**.

Recently, phototherapy, including light-emitting diodes (LED), has become a promising tool to improve muscle performance by promoting skeletal muscle recovery following exercise training and delaying the onset of muscle soreness, as mentioned by Machado et al. (2017) **(9)**.

So, this study was designed to investigate the effects of LED when combined with exercise programmes on hand grip strength in burn cases.

MATERIALS AND METHODS:

1. **Participants:**

60 males with partial thickness hand burns participated in this study. They were selected from the burn unit in Om-Al-Misryeen general hospital (Ministry of Health) Orabi hospital and randomly distributed into two equal groups. Their age ranged between 20-40 years, all participants with systemic diseases, peripheral vascular diseases, associated injuries, signs of wound infection, or any problem that affects the healing or functionality of the hand were excluded from the study. The study was approved by the faculty of physical therapy ethical committee review board (No. P.T.REC/012003009) on November 10, 2020.

2. **Outcome measures:**

The total active range of motion (TAM) of the digits and hand grip strength were measured for all participants before and after treatment.

2.1 Total active ROM

Total active ROM is the sum of active ROM that occurs at the metacarpophalangeal (MP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints of one digit (6). It was measured by a hand-held finger-standard goniometer. With the wrist in a neutral position. TAM was computed using the American Society for Surgery of the Hand (ASSH)'s recommended method, and flexion measurements of the MCP, PIP, and DIP joints were summed up. For the thumb, the MCP and IP range joints were measured, and any extension loss at each of the joints was subtracted from the total flexion. The results of these measurements were classified into four categories: a) Normal TAM: >2608, Excellent TAM: 2200–2598, Good TAM: 1800–2198, and Poor TAM: <1800 **(10)**.

2.2 Hand grip strength test

A calibrated hydraulic JAMAR (Model: 10542133, Preston Jackson, MI 49204, LAFAYETTE INSTRUMENT COMPANY, Indiana), grip strength was measured by an analogue hand-grip dynamometer with the patient in a sitting position (with 90° flexion at the hip, knee, or elbow and the shoulder in a neutral position); the forearm was kept neutral and supported by the armchair **(11)**. Every patient was allowed to practice the movement once, after which he was allowed three maximum voluntary contractions. A 15-second rest was maintained between trials. The average peak force (kg) was noted for each hand. For the sake of consistency, test trials were conducted under the same conditions (i.e., in a quiet environment, in the morning, and supervised by the same investigator) (6).

3. **Light emitting diode device:**

For treatment, an LEDT device was used with wavelengths of 630, 660, and 850 nm, a spot size of 2.5 cm2, and a power density of 120 mW/cm2. The treatment was performed in non-contact mode with the probe held stationary at a vertical distance of 1 inch between the skin and the light source. The duration of treatment was 20 minutes, as recommended by Yang et al. (2012) **(12)**. During the treatment, patients were seated with their forearms supinated and supported on a table during the treatment. The center of the LED spot was placed at approximately 50% of a landmark line drawn between the medial epicondyle and the ulnar styloid process, which corresponds to the center belly of the flexor digitorum superficialis muscle. The patients were instructed to keep their forearm still without moving it throughout the treatment session (12). LED is performed before an exercise programme.

STATISTICAL ANALYSIS:

To test the data for normality, the Shapiro-Wilk test was conducted. While the chi squared test was conducted for comparing the mean values of treated side distribution, an independent t-test was used to compare the mean values of grip strength between both groups following treatment, while the Mann-Whitney test was used for comparing the mean values of age and total active motion between the two groups before and after treatment and comparing pre-treatment Grip strength between both groups. Paired t tests were used to compare pre- and post-treatment mean values of Total active motion in group A, while Wilcoxon test was used for comparing the pre- and post-treatment mean values of Total active motion in group B and Grip strength in both groups. The arithmetic means as an average description of the central tendency of the results. The standard deviation as a mean of dispersion of the results. The level of significance for all statistical tests was set at a P value < 0.05. All statistical measures were performed through the statistical package for social studies (SPSS) version 27 for windows.

RESULTS:

Between group comparison:

- Before the treatment, there was a non-significant difference in all treatment variables between the two groups (P > 0.05), while after treatment, there was a significant difference in grip strength and total active motion between the two groups with a P value of (< 0.001) as shown in Table 1,2.

-Negative mean difference scores (95% confidence interval [CI]) on outcome measures indicate improvement.

Within group comparison:

-As shown in Table (1,2), there was a significant difference in total active motion and Grip strength post-treatment as compared with pretreatment in both groups (P < 0.001).

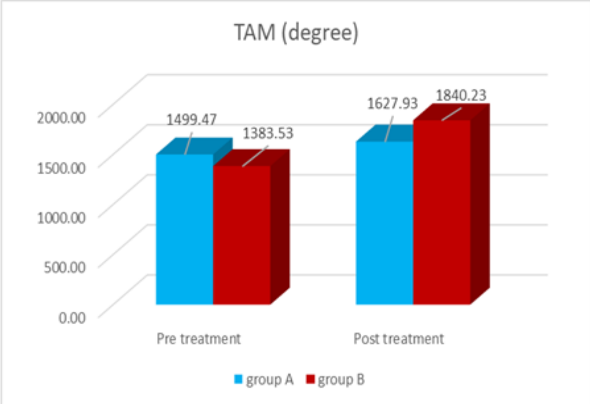

Fig. (1): Mean total range of motion (TAM) of hand.

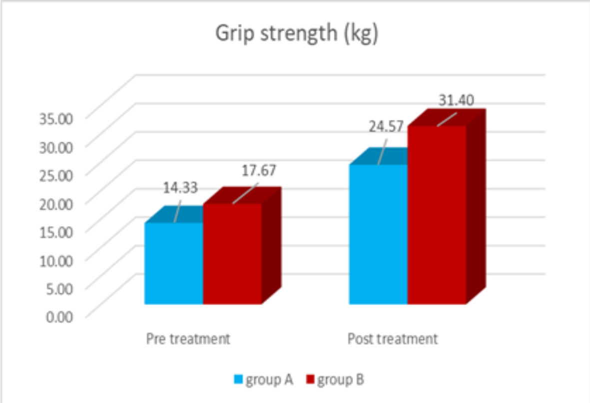

Fig. (2): Mean hand grip strength.

Table (1): Mean and standard deviations (SD) of Total Range of Motion (TAM).

Total active motion (TAM)	Pretreatment $\bar{X}$ ±SD	Post treatment $\bar{X}$ ±SD	MD	% of change	P. value	Sig
Group A (control group)	1499.47±244.06	1627.93±214.05	-128.46	8.57 %	< 0.001	S
Group B (experimental group)	1383.53±394.95	1840.23±346.65	-456.7	33.01 %	< 0.001	S
MD	115.94	-212.3				
P. value	0.131	< 0.001				
Sig	NS	S				

$\bar{X}$: Mean SD: Standard deviation MD: Mean difference
P. value: Probability value S: Significant NS: Nonsignificant

Table (2): Mean and standard deviations (SD)of hand grip strength.

Grip strength	Pretreatment $\bar{X}$ ±SD	Post treatment $\bar{X}$ ±SD	MD	% of change	P. value	Sig
Group A (control group)	14.33±12.09	24.57±6.58	-10.24	71.46%	< 0.001	S
GroupB (experimental group)	17.67±3.28	31.40±4.91	-13.73	77.70%	< 0.001	S
MD	-3.34	-6.83				
P. value	0.097	< 0.001				
Sig	NS	S				

$\bar{X}$: Mean SD: Standard deviation MD: Mean difference
p value: Probability value S: Significant NS: Nonsignificant

DISCUSSION

This study aimed at evaluating the combined effect of LED device and exercise therapy on hand grip strength in burn patients. Even though hand burns are not associated with a high risk of mortality, they can contribute to severe functional impairments as the hand is responsible for carrying out most of the daily activities. This directly affects the QoL of burn survivors and is considered a strong predictor of social reintegration and work setting following hand burns. Thus, restoring optimal hand function comes on top of the rehabilitation goals for hand burn survivors. Hand patients often complain of residual scarring and contractures that result in ROM limitation. Improper or delayed rehabilitation can significantly result in residual hand dysfunction **(4).**

Physical exercise significantly reduces burn-induced complications. Thus, including strengthening exercises in burn rehabilitation programmes regimens is crucial. When compared to standard care, a combination of progressive training and standard care in hand survivors significantly increases lean body mass, muscle strength, and power and enhances the assimilation of amino acids into muscle proteins **(13).** Moreover, physiotherapy is indispensable in burn patients because it directly prevents adhesions, contractures, and ROM limitation **(14).**

Several studies have used photobiomodulation (PBMT) in the form of light-emitting diode therapy (LEDT) as a new innovative method to improve the performance of different muscle groups as well as hand muscles, and their studies have shown promising results,

(**15, 16).** However, no previous study has been implemented to investigate its effect on burn victims who have impaired hand function because of wounds as well as muscle weakness due to burn consequences that make rehabilitation challenging.

The LEDT device selected for the study offers both red and IR ranges (wavelengths 630 nm, 660 nm, and 850 nm), as several studies have demonstrated positive effects of this wavelength range on muscle performance **(17).**

The present study showed that both groups had greater values of grip strength compared with the baseline. Additionally, both groups showed significantly greater values of total range of motion after exercise treatment. These findings demonstrate that the treatment protocol was effective. However, there is a significant improvement in TRM and grip strength in the group received pre-exercise LEDT compared to the control group. This result is similar to the study performed by **Florianovicz et al., 2019 (18)** on 58 females with previous hand injuries to investigate the effects of PBMT combined or not with Restriction of Wrist Extensor Blood Flow (BFR) on wrist extensor muscle strength and electromyograph activity. Although there was an increase in grip strength in the group that received the PBMT-associated BFR protocol, there were also satisfactory improvements in the PBM group compared to the exercise-only group only with preferable results when a wavelength of 660 nm was used rather than 830 nm. While this study was conducted on healthy participants, both clinical and experimental research refers to the benefits of PBMT application to decrease oxidative stress and boost muscle performance, not only in healthy subjects but also in those with metabolic or orthopaedic conditions.

De Araújo et al., 2017 (19) also performed a study to compare the effects of LED and cryotherapy on hand grip strength and blood lactate removal in Brazilian Jiu-Jitsu (BJJ) practitioners. They revealed that LED therapy facilitates the recovery of maximum hand grip strength when compared to passive recovery, which indicates the beneficiary nature of LED in short-term recovery, although they had similar results with groups treated by cryotherapy.

It has been proven that a single application of LED before exercise training can effectively maintain grip strength and reduce muscle fatigue and damage in elderly women. Levels of creatine kinase (CK) did not change after the training programme; also, the number of repetitions increased by 22.0% **(20).** Similar results were found by **Macagnan et al. 2018 (21)** in a study performed on patients with chronic kidney disease during hemodialysis.

The mechanism by which photobiomodulation (PBMT) increases muscle performance and accelerates tissue recovery following exercise remains unclear. However, low intensity light-emitting diodes and LASER are known to emit light that can be absorbed by the cells' photoreceptors, initiating a series of biochemical and molecular reactions that improve inflammatory control and decrease oxidative stress. Thus, the results of exercise are enhanced, and muscle recovery is promoted **(22).**

Several hypotheses have been introduced to elaborate on the effect of LEDT on muscles. First, it was hypothesised that cytochrome c oxidase (protein expression and/or enzyme activity) can enhance mitochondrial transport and facilitate ATP synthesis by aerobic metabolism, generating more energy that includes creatine phosphate resynthesize and resulting in enhanced myocellular metabolism. Thus, it improves muscle performance when it comes to strength, endurance, power, repetitions, and faster recovery after exercise. Another hypothesis stated that phototherapy improves cells and tissues responses to metabolic and mechanical stresses **(23).**

Ferraresi et al. 2016 (22) conducted a study on exercise-trained mice and evaluated glycogen in their muscles. They revealed that when phototherapy was applied, muscle glycogen was restored quickly, which suggests the positive effect of LEDT on glucose metabolism throughout glycolysis. They also suggested a possible increase in glucose transportation into cells. Several studies have also reported a balance between the production and reduction of reactive oxygen species

(ROS) in improving muscle performance and preventing cellular damage following intense exercises. Thus, it was suggested that LEDT protects against exercise-induced muscle damage and modulates ROS, which is a natural product of exercise.

The availability of muscle energy and lower ROS are two important factors in determining the speed of post-exercise recovery. Recovery from microdamage or microlesions takes place as a result of activating satellite cells and adding new myo-nuclei in muscle cells, resulting in an enhanced cascade of protein synthesis that encourages hypertrophy and repair. It has been proven that LEDT can facilitate muscle cell proliferation by activating satellite cells after training. Rapid synthesis of new muscle proteins to restore muscle damage as well as increased myonuclei per muscle cell both lead to an enhanced myonuclear domain **(24).**

Phototherapy's effects can last for as long as 24 hours (in vitro and in vivo) and can possibly last for up to 48 hours in human skeletal muscles. When LEDT was compared with placebo treatment, it was evident that LEDT made muscles more resistant to fatigue, decreased the concentration of Creatinine Kinase (CK), which is highly indicative of muscle damage, and decreased delayed-onset muscle soreness (DOMS). Furthermore, LEDT improved the achievable maximal load in training, as well as the expression of genes responsible for defending the body against oxidative stress, boosted protein synthesis, and produced MRI-proven increase in the cross-sectional area of the muscle **(22).** All these biochemical and physiological changes are followed by significant functional changes. For example, muscle strength and endurance, power, torque, and hypertrophy positively affect physical fitness and overall performance **(25).**

In addition to its positive effects on muscular performance. LEDT also improves the tissue repair process following burns and, therefore, remodulates the inflammatory process associated with healing. These effects have been repeatedly reported in the literature. **Simões et al. 2022 (26)** reported a higher count of inflammatory cells at seven and 14 days following injury. In this study, a group was treated with red LED, and the results were compared to a control group with a predominance of neutrophils and lymphocytes at seven days and an increase in the number of local blood vessels. In addition, LED therapy is capable of blocking the action of reactive oxygen species (ROS), which are generated during oxidative stress and are harmful to healing. Better tissue organisation can be promoted by LED therapy, with a larger granulation tissue area.

Finally, it can be concluded that LEDT effectively improved hand grip by relying on three elements that affect hand function in burn victims: the elimination of pain, acceleration of wound healing, and enhancement of muscle performance.

CONCLUSSION

Based on several previous studies as well as the results of the current study, LED is a safe and effective modality for improving hand grip strength in 2nd-degree burn victims when applied before hand exercise.

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