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# Physical therapy in burn care: Development of clinical prediction rules to determine the efficacy of low-level laser therapy

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## ABSTRACT

This study aimed to demonstrate the benefits of low-level laser therapy (LLLT) on burn healing and to investigate whether patients' age, burn wound size, wound stage, and total burned surface area influence the burn wound healing response to LLLT. This was a quasi-experimental study with a single-group design that included eighty male and female patients with partial-thickness burn wounds recruited from burn units. The participants were placed in a single intervention group receiving LLLT. The duration of the intervention was six weeks, divided into 18 sessions (three sessions per week). The statistical analysis was conducted using version 25 of the SPSS statistical package for Windows. The results showed a statistically significant negative relationship between wound improvement from LLLT and age ($p < 0.05$) and between total body surface area (TBSA) and wound improvement ($p < 0.05$). Additionally, a statistically significant positive relationship was found between initial wound size and wound improvement ($p < 0.05$). There was no statistically significant relationship between wound improvement and wound stage ($p > 0.05$). The current study revealed that age, TBSA, and initial wound size can predict the efficacy of low-level laser treatment for burn wounds.

## KEYWORDS

Low-Level Laser Therapy; Clinical Prediction Rules; Burn; Wounds; Patients

## 1. INTRODUCTION

Damage to biological tissues, such as the skin, organ tissues, and mucous membranes, is referred to as a wound. Various traumas can cause this damage. To prevent the spread of infection, it's crucial to ensure that wounds are properly cleaned and treated (Herman & Bordoni, 2023). Before applying any treatment, it is important to identify the type of wound. It is unlikely that a single treatment approach can be recommended for all types of wounds because different wounds vary in their biology, pathophysiology, and structure (Irfan et al., 2016).

The four phases of the wound healing process are hemostasis, inflammation, proliferation, and finally, tissue remodeling. These phases and their physiological processes must occur in the correct sequence and at the appropriate time (Pourshahrestani et al., 2020).

Burn injuries are classified into first-, second-, and third-degree burns. First-degree burns are minor injuries that affect only the epidermal layer of the skin. They do not require specific care, leave no scars, and heal within a week. Second-degree burns involve injury to the epidermis and superficial dermis. In the absence of infection, they typically heal in two to three weeks but may leave a scar. These burns can impair the deeper layers of skin and underlying skin structures (Yao et al., 2021). Third-degree burns extend to the subcutaneous tissue, muscles, and may affect deeper areas of the skin. These burns often result in scars or deformities, and skin grafting is usually necessary for healing.

Burn wounds differ from other types of wounds due to distinct physical and chemical causes, necessitating different approaches to care. While blood loss from other acute wounds may lead to shock, severe burns increase capillary permeability, causing significant plasma loss. Unlike most wounds, burn wounds are initially sterile. However, wound infection and septicemia, often caused by immunodeficiency, are the leading causes of death in individuals with severe burns. Deep burns cannot be treated with the same dressings and antibacterial treatments used for traumatic wounds (Tiwari, 2012).

Although measurement techniques may exaggerate or underestimate the size of a wound, they are still useful for assessing how efficiently it is healing. To determine the healing rate, reliable, but not necessarily perfectly accurate, measurements of wound size are required (Santamaria et al., 2012). One of the most popular methods for calculating wound area is the manual planimetric approach, which involves tracing the wound's borders. A sterile translucent film is placed over the wound, and the margins are marked. The film is then placed on a sheet of paper with a millimetric grid, and the millimeter squares within the marked area are counted (Bilgin & Günes, 2013).

Low-level laser therapy (LLLT) is defined as having an output power of less than 0.5 watts. These treatments are sometimes referred to as 'cold lasers' because they do not produce a heating sensation (Tiwari, 2012). LLLT, phototherapy, and photobiomodulation all involve the non-thermal irradiation of photons to modulate biological activity. LLLT uses coherent light sources (lasers) or non-coherent sources (filtered lamps, LEDs, or a combination of both). The primary medical uses of LLLT include controlling pain and inflammation, improving tissue repair, stimulating neurons and tissue regeneration, and preventing tissue damage in situations where it is likely to occur. For the aesthetic treatment of scars, photo-aged skin, and fine wrinkles, non-ablative laser therapies, also known as photo-rejuvenation, have gained popularity. More recently, this technique has also been used to treat inflammatory acne. LLLT involves low levels of red and near-infrared (NIR) light exposure (Cotler et al., 2015).

In medical practice, clinical prediction rules (CPRs) are often used to improve decision-making by correlating treatments with specific patient subgroups. Before a CPR can be applied, it must be validated to determine if it can enhance decision-making, influence clinical practice, improve patient outcomes, and reduce costs. This study aims to demonstrate the benefits of LLLT on burn healing, and to investigate whether patients' age, burn wound size, wound stage, and total burned surface area influence the burn wound healing response to low-level laser therapy (LLLT). This study may guide therapists in managing burn wounds and provide physical therapists with clinical guidance to select appropriate patients for LLLT, ultimately saving time and achieving better patient outcomes.

## 2. METHODS

### 2.1. Study Design and Participants

This was a quasi-experimental study with a single-group design, which included eighty male and female patients with partial thickness burn wounds recruited from burn units between December 2022 and March 2023. The participants were recruited into a single intervention group. The duration of the intervention was 6 weeks, divided into 18 sessions (three sessions per week).

The inclusion criteria required patients to have first- or second-stage wound healing, be between 20 and 50 years old, and have a total burned surface area (TBSA) greater than 15%. Exclusion criteria included patients in the third stage of wound healing, those with diabetes, patients receiving immunosuppressive drugs, and individuals with comorbidities such as neurological disorders, malnutrition, or inflammatory and infectious diseases. Ethical approval for the study was granted by the Ethical and Research Committee of Faculty of physical therapy, Cairo University IRB No: P.T.REC/012/003532.

### 2.2. Procedures

Study procedures were composed of two categories: measurement procedures and therapeutic procedures.

### 2.2.1 Measurement Procedures

1. **Preparatory phase**

In this phase, each patient achieved the following steps:

- All participants signed an institutional review board-approved informed consent statement prior to testing.
- Subjects were familiarized with the equipment and test procedures before testing commenced.
- All patients received an explanatory session before the evaluation procedure based on the established protocols.
- Primary medical history was obtained from the patient medical record, and demographic data, including age, sex, height, weight, and general health status, were recorded to determine if the patient was able to undergo the experiment.
- Measurements were performed under standardized conditions as follows: Measurements were carried out by the same investigator.

- The measurement procedures were conducted two times: before treatment application (pre-treatment) and after six weeks of treatment application (post-treatment).

2. **Measuring phase**

   The wound surface area was measured before and after treatment through the following steps:

- Each patient was assessed using a metric graph sheet to measure the wound surface area (WSA).
- The transparent grid paper was cleaned with alcohol before use and was used only once (disposable).
- It was then placed on top of the wound, and the margin of the wound was traced using a fine pen marker in cm².
- The area of the wound was calculated manually by the main investigator by counting the completely filled squares within the wound border and regrouping the partially filled squares.
- The burn wound was classified as stage I (inflammatory) or stage II (proliferative) according to the stage of healing based on clinical features and the duration of the wound.
- Total body surface area (TBSA) was measured using the Rule of Nines method.

### 2.2.2. Therapeutic procedures

This study was conducted at the in-patient burn unit of Ahmed Orabi Hospital, Egypt. Eighty male and female patients were recruited into a single intervention group. The duration of the intervention was 6 weeks, divided into 18 sessions (three sessions per week).

1. **Preparatory phase:**

   Every patient was given information about the measurement and treatment procedures before the beginning of the treatment.
2. **Application phase:**

   LLLT was performed for 30 minutes, three times per week for 6 weeks on the selected burn wound area. The wound area was irradiated with a red 655 nm light at 150 mW, delivering 2 J/cm² at the base of the wound.

### 2.3. Statistical Analysis

The statistical analysis was conducted using version 25 of the SPSS statistical package for Windows (SPSS, Inc., Chicago, IL). Descriptive statistics for quantitative data included mean and standard deviation for age, total body surface area (TBSA), and wound surface area (WSA) variables. The qualitative stage variable data are expressed as numbers and percentages. Pearson's correlation coefficient was used to compute the relationship and direction between age, TBSA, initial wound size, and the mean differences in WSA. Spearman's correlation coefficient was used to compute the relationship and direction between the stage and the mean differences in WSA. All statistical analyses were accepted at a significance level of $P \leq 0.05$.

## 3. RESULTS

In the current study, eighty patients participated, and their ages ranged from 20 to 50 years. The mean ± SD values for age, total body surface area (TBSA), and initial wound size at pre-wound surface area (WSA) were 36.20 ± 9.33, 29.44 ± 6.76, and 11.37 ± 7.98. The distribution of stages I and II was 37 (46.3%) and 32 (40.0%) (Table 1).

**Table 1.** Socio-demographic characteristics of participants

| **Variables** | **Sample (n=80)** | | |
|---|---|---|---|
| | **Mean ±SD** | **Minimum** | **Maximum** |
| Age | 36.20 ±9.33 | 20.00 | 50.00 |
| TBSA | 29.44 ±6.76 | 16.00 | 42.00 |
| Initial wound size (Pre-WSA) | 11.37 ±7.98 | 3.33 | 33.10 |
| Stages (Stage I : Stage II ) | 37 (46.3%): 32 (40.0%) | | |

*Note: Data are expressed as mean ± standard deviation for age, total body surface area (TBSA), and initial wound size; data are expressed as number (percentage) for stages.*

**Table 2.** Effect of treatment on WSA and total wound improvement

| **Variables** | **Mean ±SD (n=80)** | **Mean difference (Improvement)** | **Total wounding improvement** |
|---|---|---|---|
| Pre-WSA | 11.37 ±7.98 | 8.51±3.76 | 24571.95±5242.08 |
| Post-WSA | 2.86 ±2.59 | | |

*Note: Data are expressed as mean ±standard deviation*

The results of Table 2 demonstrate a reduction in the mean WSA from 11.37 ± 7.98 cm² before treatment to 2.86 ± 2.59 cm² after treatment, indicating effective healing. The mean difference in WSA improvement is 8.51 ± 3.76 cm²**,** reflecting a substantial average decrease in wound size post-intervention. Additionally, the total wound improvement measured as 24,571.95 ± 5,242.08 underscores the overall effectiveness of the treatment in promoting wound healing.

**Table 3.** Relationship between total wound improvement with age, TBSA, stage, and initial wound size

| Variables | Correlation coefficient (r) | ***P*-value** |
|---|---|---|
| Age | -0.002 | 0.611 |
| TBSA | -0.012 | 0.751 |
| Stage | -0.120 | 0.288 |
| Pre-WSA | -0.035 | 0.329 |

Note: Data are expressed as mean ±standard deviation; r: Person's correlation coefficient; P-value: probability value *Significant: P < 0.05.

Table 3 presented the correlation between total wound improvement and various factors, including age, TBSA, stage, and initial wound size (Pre-WSA). The correlation coefficients (r) are all low, indicating weak relationships: age (r = -0.002, P = 0.611), TBSA (r = -0.012, P = 0.751), stage (r = -0.120, P = 0.288), and initial wound size (r = -0.035, P = 0.329). None of the variables show statistically significant correlations with total wound improvement (p>0.05).

Pearson's correlation coefficients were computed between age and the mean differences of WSA (Table 4 and Figure 1). The results of these correlation analyses revealed a significant negative relationship between age and the mean differences of WSA (r = -0.480; P = 0.0001; P < 0.05). This indicates that changes in the mean differences of WSA are consistent with changes in age.

**Table 4.** Relationship between age and mean differences of WSA

| Variable: Age | Mean ±SD (n=80) | Mean difference | Correlation coefficient (r) | P-value |
|---|---|---|---|---|
| Pre-WSA | 11.37 ±7.98 | 8.51 | -0.480 | 0.0001* |
| Post-WSA | 2.86 ±2.59 | | | |

*Data are expressed as mean ±standard deviation; r: Person's correlation coefficient; P-value: probability value *Significant: P<0.05.*

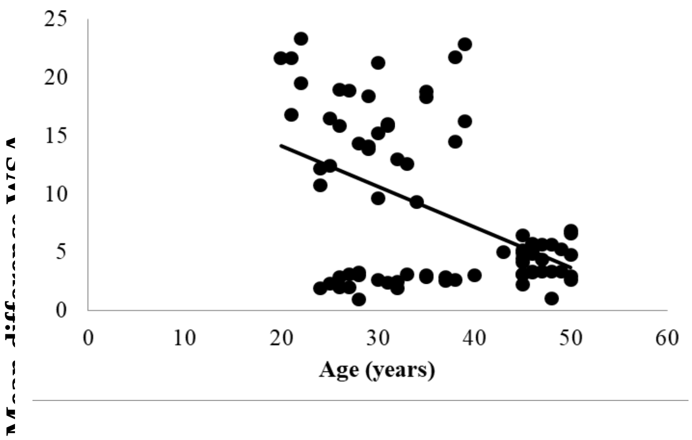

**Figure 1.** Scatter plot relation between age and mean difference of WSA

Pearson’s correlation coefficients were computed between total body surface area (TBSA) and the mean differences of wound surface area (WSA) (Table 5 and Figure 2). The results of these correlation analyses revealed a significant negative relationship between TBSA and the mean differences of WSA (r = -0.476; P = 0.0001; P < 0.05). This indicates that changes in the mean differences of WSA are consistent with changes in TBSA.

**Table 5.** Relationship between TBSA and mean differences of WSA

| **Variable (TBSA)** | Mean ±SD (n=80) | Mean difference | Correlation coefficient (r) | P-value |
|---|---|---|---|---|
| Pre-WSA | 11.37 ±7.98 | 8.51 | -0.476 | 0.0001* |
| Post-WSA | 2.86 ±2.59 | | | |

*Data are expressed as mean ±standard deviation; r: Person’s correlation coefficient; P-value: probability value*
**Significant: P< 0.05.*

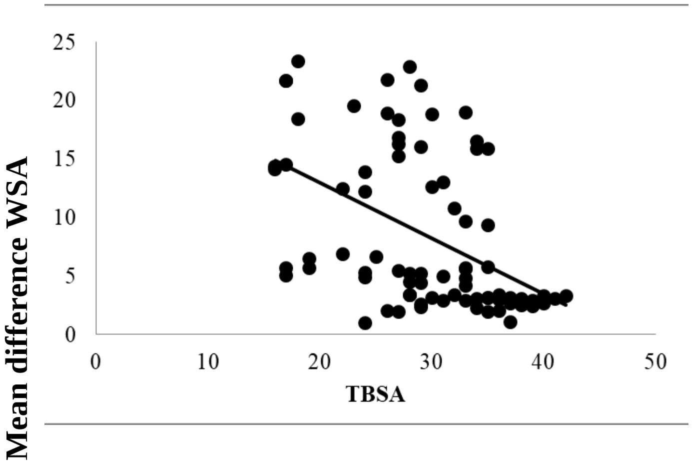

**Figure 2.** Scatter plot relation between TBSA and mean difference of WSA

Table 6 and Figure 3 present the relationship between initial wound size and the mean differences of WSA. The results of these correlation analyses revealed that there were significantly positive relations between initial wound size and the mean differences of WSA (r=0.952; P= 0.0001; P<0.05). This means that the change in the mean differences of WSA is consistent with change in initial wound size.

**Table 6.** Relationship between initial wound size and mean differences of WSA

| **Variable (Initial Wound Size)** | **Mean ±SD (n=80)** | **Mean difference** | **Correlation coefficient (r)** | ***P*-value** |
|---|---|---|---|---|
| WSA | 11.37 ±7.98 | 8.51 | 0.952 | 0.0001* |

*Data are expressed as mean ±standard deviation; r: Person’s correlation coefficient; P-value: probability value*
**Significant: P< 0.05.*

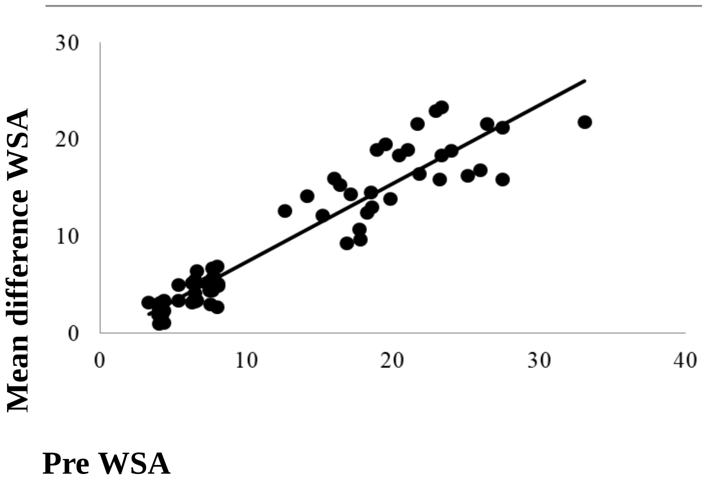

**Figure 3.** Scatter plot relation between pre-WSA and mean difference of WSA

Bi-variate Spearman correlation coefficients were calculated to examine the relationship between stage and mean differences WSA (Table 7). The results of these correlation analyses revealed no significant relationship between stage and mean differences of WSA (r = -0.272; P = 0.528; P > 0.05). This indicates that changes in the mean differences of WSA are not consistent with changes in stage.

**Table 7.** Relationship between stage and mean differences of WSA

| Variable (Stage) | Mean ±SD (n=80) | Mean difference | Correlation coefficient (r) | P-value |
|---|---|---|---|---|
| Pre-WSA | 11.37 ±7.98 | 8.51 | -0.072 | 0.528 |
| Post-WSA | 2.86 ±2.59 | | | |

*Data are expressed as mean ±standard deviation; r: Person's correlation coefficient; P-value: probability value*
**Significant: P< 0.05.*

**Table 8.** Predictive findings and their association with mean differences of WSA in the univariate and multivariate regression models

| Predictive findings | Univariate regression model | | Multivariate regression model | |
|---|---|---|---|---|
| | **β (95% CI)** | **P-value** | **β (95% CI)** | **P-value** |
| Age | -0.35 (-0.49– 0.21) | 0.0001* | -0.05 (-0.10– 0.01) | 0.077 |
| TBSA | -0.48 (-0.67– 0.28) | 0.0001* | -0.12 (-0.19– -0.05) | 0.001* |
| Stage | -0.74 (-2.88– 1.42) | 0.498 | 0.21 (-0.42 – 0.84) | 0.501 |
| Pre-WSA | 0.81 (0.75– 0.86) | 0.0001* | 0.74 (0.68 – 0.81) | 0.0001* |

*P-value: probability value; *Significant: P< 0.05.*

## 4. DISCUSSION

The current study reveals a statistically significant negative relationship between wound improvement and age ($p<0.05$), and between TBSA and wound improvement ($p<0.05$). Additionally, a statistically significant positive correlation exists between initial wound size and wound improvement ($p<0.05$). There was no statistically significant relationship between wound improvement and wound stage ($p > 0.05$).

It has been proven that LLLT accelerates burn healing (Bayat et al., 2006). A cell type called myofibroblasts is responsible in wound contraction, which is essential for the proper healing of major wounds with significant tissue and cell loss (Medrado et al., 2003). Due to their extensive positivity for a-SMA (alpha smooth muscle actin), these cell subsets can be recognized by immunohistochemistry because they exhibit a contractile phenotype and have a cytoskeleton rich in actin microfilaments (Pereira et al., 2010). It has been proposed that there may be a correlation between laser-induced up regulation of specific cytokines necessary for myofibroblastic differentiation, such as TGF-b, and the phenomenon, even though the precise mechanism is yet unknown (McGinn et al., 2000). Previous research has shown that LLLT has the ability to up-regulate the release of cytokines including FGF-a and TGF-b, which are responsible for collagen synthesis and fibroblast proliferation, respectively (Demidova et al., 2007)

Both the number and density of fibroblasts increase over the course of the experimental periods under investigation, according to the quantitative examination of samples exposed to radiation of various energies (Maligieri et al., 2017). Chiarotto et al. (2014) also reported this in second-degree burns when they utilized a 670 nm In GaP laser at 4.93 J/cm². Silveira et al. (2011) hypothesized that the acceleration of fibroblast migration and proliferation caused by this treatment was responsible for the increase in collagen observed in irradiated excisional lesions, particularly at 3 J/cm² in rats. The current study demonstrates that there is no significant relationship between wound stage and wound improvement, as the enhancement in wound healing occurred at both stages without a discernible difference. Enwemeka et al. (2004) demonstrated that all stages of tissue repair are significantly improved by LLLT and that the selection of wavelength and energy density is essential for a successful treatment course.

The outcomes of this study support the claim made in the literature that LLLT can be effectively used in clinical settings. While these lasers are not powerful enough to damage tissue, they are sufficiently effective to promote tissue repair. However, the Level IV clinical prediction rule

(CPR) generated in this investigation should not be considered the definitive CPR for guiding clinical practice (McGinn et al., 2000). Further research is needed to determine whether this increase is clinically significant. It seems unlikely that future studies will be able to accurately identify patients with 100% precision.

## 5. CONCLUSIONS

The current study revealed that age, TBSA, and initial wound size can predict the efficacy of low-level laser in treatment of burn wound. This clinical prediction rule (CPR) gives the chance to a prior identify the sub-group of burn wound patients most likely to benefit from low level laser therapy, which may enhance clinical practice decision-making. The findings of this study serve as the foundation for the creation of CPRs. Future research is required to confirm the rule's validity and ascertain how it will affect clinical practice patterns, patient outcomes, and costs.

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## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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