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**Ocena częstości występowania i stopnia nasilenia objawów nietrzymania moczu w grupie dorosłych kobiet aktywnych fizycznie**

**The frequency and severity of urinary incontinence symptoms in the group of adult physically active women**

**Czy ćwiczenia ekscentryczne mogą zredukować rozejście mięśnia prostego brzucha?**

**Can eccentric exercises reduce diastasis recti?**

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# Effectiveness of low-level laser therapy with Buerger Allen exercise versus LIPUS with Buerger Allen exercise for diabetic foot ulcer

*Skuteczność terapii laserowej niskiej mocy z ćwiczeniami Buergera-Allena w porównaniu z terapią ultradźwiękową niskiej intensywności z ćwiczeniami Buergera-Allena na owrzodzenia stopy cukrzycowej*

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## Abstract

Background: Diabetic foot ulcers (DFUs) are a severe diabetes complication with a burden similar to cancer. Risk factors include peripheral neuropathy, arterial disease, foot abnormalities, and socioeconomic and geographical influences. Low-Level Laser Therapy (LLLT) relieves pain, promotes tissue repair, and aids wound healing. Ultrasound therapy enhances circulation and tissue healing through sound waves. Buerger-Allen Exercises (BAE) improve lower extremity perfusion, aiding wound healing and reducing neuropathy symptoms. Purpose: This pilot study compared the effectiveness of LLLT with BAE versus Low-Intensity Pulsed Ultrasound Therapy (LIPUS) with BAE in managing DFUs. Methods: 40 patients were assigned to two groups (20 each). Group A received LLLT for 10 minutes, while Group B received LIPUS for 10 minutes. Both groups performed BAE for 10 minutes on alternate days, 3 days a week for 12 weeks. Outcomes were assessed using the Visual Analog Scale (VAS), Bates-Jensen Wound Assessment Tool (BWAT), and Diabetic Foot Ulcer Scale (DFS). Results: Both groups showed significant improvements ($P \leq 0.05$), but LLLT with BAE was superior in pain reduction, wound healing, and quality of life. Conclusion: LLLT with Buerger-Allen exercises is a more effective treatment for DFUs than LIPUS.

## Key words

diabetic foot ulcer, Laser therapy, Ultrasound therapy, Buerger-Allen exercise

## Streszczenie

Tło. Owłrzodzenia stóp cukrzycowych (DFUs) są poważnym powikłaniem cukrzycy o skutkach porównywalnych z rakiem. Do czynników ryzyka należą neuropatia obwodowa, choroby tętnic, nieprawidłowości stóp oraz wpływy społeczno-ekonomiczne i geograficzne. Terapia laserowa niskiej mocy (LLLT) łagodzi ból, wspomaga naprawę tkanek i przyspiesza gojenie ran. Terapia ultradźwiękowa poprawia krążenie i gojenie tkanek za pomocą fal dźwiękowych. Ćwiczenia Buergera-Allena (BAE) poprawiają perfuzję kończyn dolnych, wspomagając gojenie ran i redukując objawy neuropatii.
Cel. Niniejsze badanie pilotażowe porównało skuteczność LLLT z BAE oraz terapii ultradźwiękowej niskiej intensywności (LIPUS) z BAE w leczeniu owrzodzeń stóp cukrzycowych.
Metody. Czterdziestu pacjentów zostało przydzielonych do dwóch grup (po 20 osób). Grupa A otrzymywała LLLT przez 10 minut, podczas gdy grupa B otrzymywała LIPUS przez 10 minut. Obie grupy wykonywały BAE przez 10 minut w dni naprzemienne, trzy dni w tygodniu przez 12 tygodni. Wyniki oceniano za pomocą skali wizualnej oceny bólu (VAS), narzędzia do oceny ran Bates-Jensen (BWAT) oraz skali owrzodzeń stopy cukrzycowej (DFS).
Wyniki. Obie grupy wykazały znaczące poprawy ($P \leq 0,05$), ale LLLT z BAE było skuteczniejsze w redukcji bólu, gojeniu ran i poprawie jakości życia.
Wnioski. LLLT z ćwiczeniami Buergera-Allena okazało się bardziej skutecznym leczeniem owrzodzeń stopy cukrzycowej niż LIPUS.

## Słowa kluczowe

owrzodzenia stopy cukrzycowej, terapia laserowa, terapia ultradźwiękowa, ćwiczenia Buergera-Allena


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## Introduction

Diabetic Foot Ulcers (DFUs) are wounds that penetrate the epidermis and extend into the dermis, often leading to infection, hospitalization, amputation, or death. The lifetime risk of DFU ranges from 19% to 34% and may rise due to increasing lifespans and the prevalence of complex medical conditions in diabetes patients. [1]. Approximately 1 to 4.5 lower limb amputations occur annually per 1,000 people with diabetes, with minor amputations outpacing major ones due to declining rates of significant amputations [2]. Globally, 15–25% of people with diabetes will develop DFUs in their lifetime [3], and in India, 74 million diabetics are at risk of DFU-related complications, contributing to increased morbidity and mortality [4]. Risk factors include peripheral vascular disease, loss of protective foot sensation, deformities, trauma, and poor glycemic control [5].

Managing DFUs is challenging for clinicians due to their complexity and cost, rivaling some cancers. DFU management costs exceed $1 billion annually worldwide, affecting both developed and developing countries [7]. DFUs result from trauma, poor glycemic control, neuropathy, vascular disease, and infections [8]. Wagner's classification is a widely used tool for assessing diabetic foot lesions to guide treatment [9].

Low-Level Laser Therapy (LLLT) and Low-Intensity Pulsed Ultrasound (LIPUS) are promising non-invasive interventions. LLLT promotes granulation, wound contraction, and re-epithelialization, accelerating healing and reducing the need for invasive procedures such as skin grafting [10]. It influences physiological and biochemical healing processes effectively and safely, with no reported side effects [11, 12]. LIPUS uses pulsed sound waves at low intensity to enhance wound healing through non-thermal and non-cavitational mechanisms [13-15], showing promise in chronic wound healing [16]. LLLT also reduces pain, while other modalities like ultrasound, TENS, and IFT offer short-term relief [17].

Buerger-Allen Exercise (BAE) enhances lower extremity perfusion by promoting vascular dilation, decreases peripheral neuropathy symptoms through improved circulation, and aids wound healing by increasing oxygen delivery to tissues [18, 19]. This technique uses interval, progressive, and gravitational foot movements to increase oxygen and nutrient demand in affected arteries and veins [20].

This study aimed to compare the effectiveness of Low-Level Laser Therapy (LLLT) combined with Buerger-Allen Exercises versus Low-Intensity Pulsed Ultrasound (LIPUS) with Buerger-Allen Exercises in managing diabetic foot ulcers. The objective was to evaluate their impact on pain reduction, wound healing, and quality of life in patients with Grade I and II diabetic foot ulcers.

## Methods

A comparative pilot study was conducted to evaluate the effectiveness of Low-Level Laser Therapy (LLLT) versus Low-Intensity Pulsed Ultrasound Therapy (LIPUS) combined with Buerger-Allen Exercises in managing diabetic foot ulcers, with institutional ethical approval obtained. Forty participants with a confirmed diabetes diagnosis (≥1 year) were included, aged between 35-55 years old, with Grade I and II foot ulcers according to Wagner classification, VAS scoring between 4-7, and a blood sugar level more than 200 mg/dL randomized into two equal groups (20 each)/ Excluding those with uncontrolled diabetes (HbA1c > 9%), cardiac and respiratory problems, ulcers not caused by diabetes, presence of osteomyelitis, or Stage 3 & 4 diabetic neuropathy. Informed consent was obtained, and baseline data were collected.

Group A received LLLT (660 nm, 4–8 J/cm² for 10 minutes) targeting the ulcer bed, while Group B received LIPUS (3 MHz, 0.5 W/cm², 1:4 pulse ratio for 10 minutes). Both groups performed Buerger-Allen Exercises (3 repetitions, 5 times daily, for 10 minutes) thrice weekly for three months. Buerger-Allen Exercises promote peripheral circulation by sequentially elevating, lowering, and resting the legs (Figure 1-3) [20].

### Outcome Measures

Outcome measures included the Visual Analog Scale (VAS) for pain, the Bates-Jensen Wound Assessment Tool (BWAT) for wound healing, and the Diabetic Foot Ulcer Scale (DFS) for quality of life. The VAS is a reliable 10-cm scale for pain intensity, ranging from 0 (no pain) to 10 (worst pain) [21, 22]. The BWAT scores wound characteristics like size and depth, with a range of 9 to 65, where higher scores indicate poorer healing [23, 24]. The DFS evaluates the impact of DFUs on patients' quality of life through a 64-item questionnaire, with each item scored on a scale of 1 to 5 [25, 26].

### Statistical Analysis

Data analysis was performed using SPSS version 24 with a 95% confidence interval. Shapiro-Wilk tests confirmed normal data distribution and parametric tests (paired and independent t-tests) were used to assess intra- and intergroup differences.

**Figure 1. Buerger allen exercise [step 1]**


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**Figure 2. Buerger allen exercise [step 2]**

**Figure 3. Buerger allen exercise [step 3]**

## Result

A comparison of the VAS scores showed a significant decrease in post-test mean values. Group A demonstrated a lower mean value (2.45 ± 0.944) compared to Group B (3.55 ± 0.944), indicating a greater reduction in pain for Group A ($p \leq 0.05$).Thus, the null hypothesis is rejected.

Statistically significant post-test reductions were observed in BWAT scores in both groups ($p \leq 0.05$). Group A exhibited a lower mean value (19.45 ± 3.28) than Group B (24.45 ± 3.11), reflecting better wound healing in Group A ($p \leq 0.05$). This finding indicates statistical significance, as shown in Table 1 and Figure 4.

DFS Scores showed a significant post-test increase, with Group A achieving a higher mean value (73.25 ± 5.75) than Group B (64.95 ± 4.35), indicating a better quality of life in Group A ($p \leq 0.05$). The null hypothesis is rejected (Table 2 & Figure 5).

Post-test comparisons of VAS, BWAT, and DFS scores showed statistically significant differences ($p \leq 0.05$), with Group A consistently achieving better results than Group B.

**Table 1. Comparison of BWAT score within group – A and group – B between pre-test and post-test**

| GROUPS | PRE-TEST | | POST-TEST | | t - TEST | SIGNIFICANCE |
|---|---|---|---|---|---|---|
| | MEAN | S.D | MEAN | S.D | | |
| GROUP- A | 35.05 | 3.81 | 19.45 | 3.28 | 29.42 | .000** |
| GROUP- B | 34.15 | 4.30 | 24.45 | 3.11 | 19.69 | .000** |

*(**- P ≤ 0.05 - Significant)*

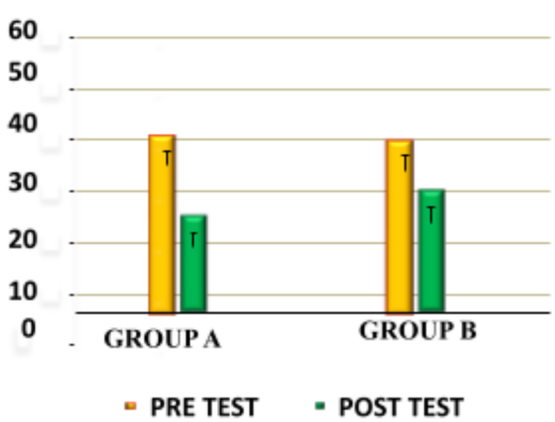


**Figure 4. Comparison of BWAT score within group – A and group – B between pre-test and post-test**


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**Table 2. Comparison of DFS score within group – A and group – B between pre-test and post-test**

| GROUPS | PRE-TEST | | POST-TEST | | t - TEST | SIGNIFICANCE |
|---|---|---|---|---|---|---|
| | MEAN | S.D | MEAN | S.D | | |
| GROUP- A | 55.90 | 5.06 | 73.25 | -5.75 | -18.22 | .000** |
| GROUP- B | 55.45 | 3.70 | 64.95 | 4.35 | -14.68 | .000** |

*(**- P ≤ 0.05 - Significant)*

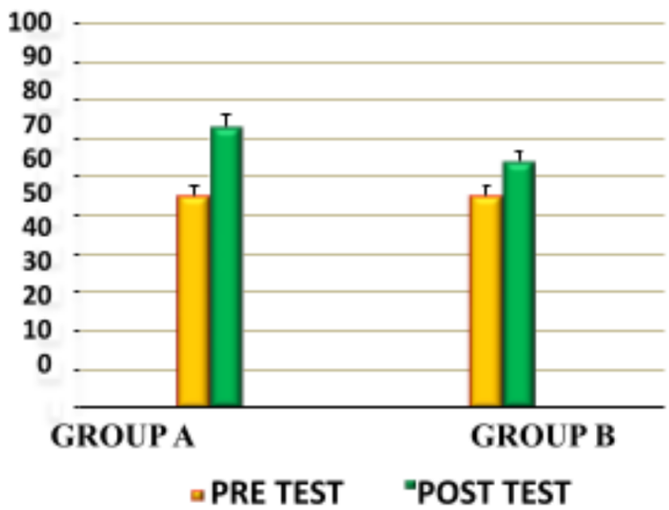


**Figure 5. Comparison of DFS score within group – A and group – B between pre-test and post-test**

## Discussion

The study compared low-level laser therapy (LLLT) with low-intensity pulsed ultrasound (LIPUS) in managing diabetic foot ulcers (DFU). LLLT combined with Buerger Allen exercises (Group A) promoted healing, reduced pain, and improved functional outcomes more effectively than LIPUS with Buerger Allen exercises (Group B).

LLLT demonstrated significant benefits, including enhanced pain relief, anti-inflammatory effects, improved tissue perfusion, and better vascular and nervous system responses. These findings align with studies by Maura Cristina Porto Feitosa et al. (2015) and Cristiana Maria Dos Santos et al. (2020), which reported accelerated tissue repair, reduced healing time, and increased complete healing rates with LLLT. In contrast, LIPUS promoted wound healing primarily through angiogenesis and cellular stimulation but was less effective than LLLT. Including Buerger Allen exercises improved circulation and ulcer healing in both groups, consistent with findings by Nuniek Tri Wahyuni et al. (2022).

Mechanistically, LLLT supports cellular proliferation, modulates inflammation, and promotes angiogenesis and collagen synthesis, addressing multiple facets of wound healing. LIPUS, while effective in stimulating microvascular flow and cellular repair, may lack the comprehensive benefits of LLLT [10, 11].

This study had several limitations, including a three-month duration, small sample size, and restriction to patients aged 35-55 with Type II diabetic foot ulcers. It also focused exclusively on pulsed ultrasound therapy. Future studies could address these limitations by including a larger sample size, extending the study duration and follow-up period, exploring different therapeutic modalities, and including patients with Type I diabetes.

Clinically, LLLT may be preferable for severe or chronic wounds requiring rapid healing, while LIPUS may serve as an adjunct for less severe ulcers or cases emphasizing mechanical stimulation [12]. LLLT's broad therapeutic effects make it a valuable tool in managing advanced DFUs, while LIPUS may complement other treatments in a multidisciplinary care approach.

## Conclusion

It is concluded that both Low-Level Laser Therapy with Buerger Allen Exercise and LIPUS with Buerger Allen Exercise significantly reduce pain, improving ulcer healing and quality of life. However, there is a highly significant improvement in Group A, which was treated with low-level laser therapy and the Buerger Allen exercise. Incorporating low-level laser therapy with Buerger Allen exercise into routine clinical practice can significantly enhance pain management, accelerate ulcer healing, and improve the overall quality of life for patients with diabetic foot ulcers, especially those with chronic or severe conditions.

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