Case Report: Photobiomodulation With Customized Insoles on Maximum Plantar Pressure in Diabetic Foot Syndrome by the Biomechanical Model: A Case Report

Hrishikesh Yadav Korada1, G Arun Maiya2*, Sharath Kumar Rao3, Manjunath Hande4

1. Centre for Diabetic Foot Care and Research, Department of Physiotherapy, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, Karnataka, India.
2. Department of Physiotherapy, Manipal College of Health Professions, Centre for Diabetic Foot Care and Research, Kasturba Hospital, Manipal Academy of Higher Education, Manipal, Karnataka, India.
3. Department of Orthopedics, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, Karnataka, India.
4. Comprehensive Geriatric Clinic, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, Karnataka, India.

* Corresponding Author:

G Arun Maiya, PhD.
Address: Centre for Diabetic Foot Care & Research, Kasturba Hospital, MAHE (Deemed University & Institute of Eminence), Manipal - 576104
Karnataka, India.
Tel: +919 (919) 845350823
E-mail: arun.maiya.g@gmail.com

ABSTRACT

A 49-year-old male patient with type 2 diabetes mellitus and Diabetic Foot Syndrome (DFS) was evaluated by comprehensive diabetic foot assessment. A 10-session photobiomodulation therapy (low-level laser therapy) was prescribed for neuropathic pain and symptoms applying the scanning and probe method. Customized insoles were recommended for redistributing the plantar pressures and reducing stress on the diabetic foot’s plantar surface for 4 weeks. Dynamic plantar pressure distribution, lower limb kinematics, and postural sway were evaluated using WinTrack dynamic pressure platform. Photobiomodulation therapy with customized insoles is useful in the redistribution and treatment of plantar pressure and gait kinematics. This approach should be extensively used in DFS as preventive and treatment measures.
Highlights

- This study was the first attempt to incorporate photobiomodulation with the customized insole.
- Detailed biomechanical analysis was evaluated in this research.
- The explored clinical and biomechanical parameters indicated significant improvements.

Plain Language Summary

Individuals with type 2 diabetes mellitus can develop symptoms, such as pain, burning sensation along increased pressure at their foot, which can cause ulcers. Numerous treatment approaches are available for this condition. Noninvasive management, like laser treatment with adjusted insoles, can reduce pain and pressure in the feet.

1. Introduction

Diabetic Foot Syndrome (DFS) is defined as a multi-factorial clinical triad of neurological, vascular, and musculoskeletal changes induced by diabetic peripheral neuropathy [1]. The overall prevalence of DFS, according to the International Working Group on the Diabetic Foot (IWGDF) Risk Classification System, is reported to be 51.8% in India; it is a common reason for hospitalizing patients with diabetes and its related complications [2, 3]. Biomechanical changes and foot deformity due to motor neuropathy; the loss of protective sensation induced by sensory neuropathy; and autonomic alternations, such as fissures, callus, bunion contribute to the altered plantar pressure distribution and ankle kinematics of DFS. Accordingly, such conditions lead to an increase in the incidence of the generation of diabetic foot ulcers [4].

2. Case Presentation

A 49-year-old male patient with a 10-year history of type 2 diabetes mellitus presented to a diabetic foot clinic. His chief complaints were frequent burning and pricking sensation on feet for 3 years. He was under oral hypoglycemic pharmacotherapy for 5 years. His demographic findings are explained in Table 1. Besides, after providing an informed consent form, a comprehensive diabetic foot evaluation form was performed to obtain a detailed diabetic foot evaluation (Table 2). This study was approved by the Institutional Ethics Committee of Kasturba Medical College and Hospital (IEC169/2019).

At the baseline, dynamic plantar pressure distribution (3-sec duration, 100 images per second, 100 Hz) and postural sway (30 sec 1200 images, 40 Hz, one parameter) were evaluated using WinTrack dynamic pressure plate (WinTrack, France). The 3-step gait protocol indicated good reliability, with Intraclass Correlation Coefficient (ICC) values ranging between 0.75 and 0.90 in gait parameters. He was instructed to walk on the platform at a reasonable pace. Three trials were conducted, and the relevant data were extracted and analyzed by WinTrack software. Photobiomodulation therapy (low-level laser therapy) was prescribed for neuropathic pain and symptoms. A scanning laser wavelength of 632.8 nm with the dose of 3.1J/cm² (TECH LASER SS-1000, Technomed, India) at the plantar and dorsal surface of the foot (6 min each), the probe laser wavelength of 660 nm and 850nm (THOR Laser Pro, THOR Photomedicine Ltd, USA) with the dosage of 3.4J/cm² by contact method at popliteal fossa (Figure 1)*3 min were implemented. Ten regular sessions of photobiomodulation were conducted.

The LASER equipment was calibrated with a Laser Photometer Power meter kit. Customized insoles were recommended for redistributing the plantar pressures and reducing stress on the diabetic foot’s plantar surface. The insole was developed by FootBalance equipment. FootBalance medical insoles were applied for molding. It is a 1.2mm thick insole made with 4 layers. The outermost layer is a Durable top layer with an antibacterial coating. The middle layer is Comfortable, a high-quality shock absorption base layer. Initially, the study participant was requested to stand barefoot on the transparent mirror on the FootBalance platform and data analysis was conducted. Then, the study participant’s foot arch was kept in 3 functional positions; standing straight, knees bent 45° and standing with toes extension. Comparing their arch matching was performed by the closest type of medial arch type was selected. An appropriate foot size insole was selected and inserted into the heating rack. We placed the warm insole between the study par-
Table 1. The demographic data of the study participant

| Variables                        | Values  |
|----------------------------------|---------|
| Age, y/Gender                    | 49/M    |
| Weight, kg                       | 95.9    |
| Height, cm                       | 186     |
| BMI, kg/m²                       | 27.7    |
| The duration of diabetes, y      | 10.2    |
| FBS                              | 127     |
| PPBS                             | 196     |
| Blood pressure (systolic/diastolic), mm Hg | 125/80  |
| HbA1c (%)                        | 9.1     |

Table 2. Clinical findings from a detailed diabetes foot evaluation

|                      | Right Foot | Left Foot |
|----------------------|------------|-----------|
| **On Observation**   |            |           |
| Dry skin             | Present    | Present   |
| Altered skin color   | Present    | Present   |
| Ingrown nails        | Present    | Present   |
| Callus               | Present    | Absent    |
| Fissures             | Present    | Present   |
| **On Examination**   |            |           |
| Skin temperature (°C)| 33.1       | 32.8      |
| Sensation            | Present    | Present   |
| Ankle reflexes       | Diminished | Diminished|
| Pedal pulse          | Palpable   | Palpable  |
| Monofilament         | 3/6        | 4/6       |
| Vibration perception threshold (V)| 32    | 25        |
| Ankle-brachial index | 1.05       |           |

The reassessment was performed at the end of the fourth week to compare the pre-post changes of vibration perception threshold, plantar pressure distribution changes, and postural sway (Table 3).

3. Discussion

The present study data suggested a change in various biomechanical parameters. In the right foot, a reduction...
of APP 11.9%, MPP to 6.5%; and in the left foot, APP 11.1% and 31.2%, respectively were detected. The total contact area of the right and left feet increased by 17.6% and 41.1%, respectively. The forefoot hindfoot ratio is also a predictor of developing forefoot ulcers; the higher the ratio, the higher the risk. The combined intervention has reduced the ratio of foot pressures [5]. Vibration Perception Threshold (VPT) is a sensory test to evaluate the extent of the loss of protective sensation in diabetic peripheral neuropathy. Values more than 20V were considered along with the inability to perceive 10gr monofilament for at least one point to be peripheral neuropathy. In

Table 3. Plantar pressure distribution parameters

| Variables                         | Right Foot   | Left Foot   |
|-----------------------------------|--------------|-------------|
|                                   | Pre-intervention | Post-intervention | Pre-intervention | Post-intervention |
| Average plantar pressure (kPa)    | 126.8        | 111.7       | 120.1          | 106.7 |
| Maximum Plantar Pressure (kPa)    | 293.6        | 274.4       | 316.9          | 217.7 |
| Pressure. Time integral (kPa.s)   | 67.52        | 51.33       | 57.07          | 36.36 |
| F/H Ratio                         | 1.40         | 1.45        | 1.22           | 1.41 |
| Step duration (ms)                | 720          | 755         | 510            | 655  |
| Swing duration (ms)               | 1360         | 1565        | 1360           | 1615 |
| Step length (mm)                  | 578          | 578         | 422            | 508  |
| Gait cycle duration (ms)          | 1000         | 1410        | 1000           | 1412 |
| Total contact area (cm²)          | 102          | 127         | 99             | 140  |
| Stride duration (ms)              | 2080         |             | 2370           |      |
| Gait cycle length (mm)            | 1230         |             | 1086           |      |
| Double stance duration (ms)       | 200          |             | 305            |      |
| CoP length (mm)                   | 323.4        |             | 273.3          |      |
| CoP Area (mm)                     | 365.2        |             | 198.7          |      |
| Length/Area (per mm)              | 0.9          |             | 1.4            |      |
| X speed (mm/s)                    | 7.5          |             | 6.1            |      |
| Y speed (mm/s)                    | 6.2          |             | 5.5            |      |
the first 10 sessions, VPT has been improved from 32V in the right to 25V in the left to 9V and 7V, respectively.

Kinematic parameters were also improved from pre- to post-intervention; especially stride duration, gait cycle length, and double stance duration. This finding reflects that the gait pattern was improved. Furthermore, the gait alterations were reduced for better propulsion of the foot during gait [6]. Balance is also the main component altered in diabetic peripheral neuropathy. Postural sway is among the gold standard methods with quantifiable variables. Variables, such as CoP length, CoP Area, X, and Y-axis speed, Y-axis deviation, have significantly improved in the explored patient. CoP length revealed increased postural stability in the patient. This may be attributed to enhanced plantar sensory perception induced by elevated neural activity at the lower peripheral nerves.

In this study, we have explored static and kinetic spatiotemporal parameters. Moreover, kinetic and kinematic characteristics were examined by the biomechanical model generated in the gait pattern. Photobiomodulation therapy is a noninvasive non-pharmacological modality based on the principle of bio-stimulation effect. Thus, PBMT significantly improves sensory perception. The potential mechanism might be due to PBMT that may prevent motor cell degeneration; induce Schwann cell proliferation; boost neural metabolism, and increase myelination and axon regeneration [7, 8].

For individuals with diabetic neuropathy, custom insoles are frequently prescribed to offload high pressure from the Metatarsal Heads (MTHs) and other regions that reduce the risk of plantar ulceration [9]. Insoles provide the critical interface between the foot and the shoe; they also present the most effective approach to minimizing potentially damaging tissue tension on the plantar part of the foot along with outsole modification [10]. The Diabetic Feet Australia guidelines on footwear for individuals with diabetes also recommended the appropriate footware with customized insoles can reduce the plantar pressures at the plantar surface of diabetic foot. It also highlighted the reduction of >30% in the region with the highest plantar pressure, compared to the same region of foot considered as plantar pressure effect [11].

4. Conclusion

Photobiomodulation therapy with customized insoles is useful in the redistribution and treatment of plantar pressure and gait kinematics. It should be extensively employed in DFS as preventive and treatment measures. However, this study was a case report, further detailed analysis and experimental study designs with long-term follow-up would help to strengthen this argument regarding the effectiveness of this approach.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors’ contributions

All authors equally contributed to conducting the study and drafting the manuscript.

Conflict of interest

The authors declared no conflicts of interest.

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