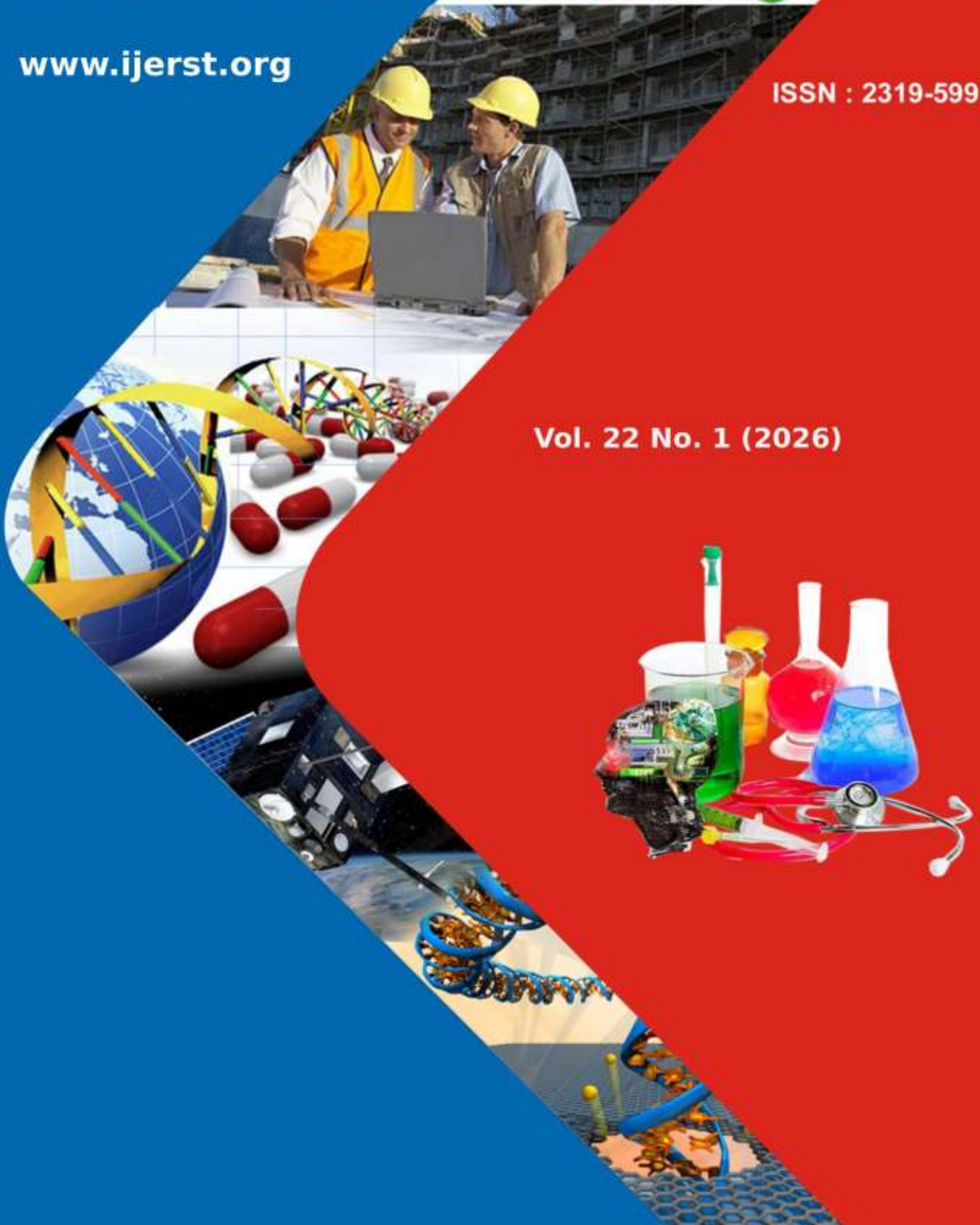
IJERST

International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991



Vol. 22 No. 1 (2026)

ijerst.editor@gmail.com

editor@ijerst.com

ISSN 2319-5991 www.ijerst.com
Vol. 22, No. 1, 2026

Research Paper

Prosthetic Sock for Early Detection of Infection of Foot Ulcer

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***Abstract*— Diabetic foot ulcers (DFUs) represent a serious complication affecting approximately 25% of diabetic patients during their lifetime. They result from neuropathy, vascular disease, and high plantar pressure, often going unnoticed due to reduced sensation. If not detected early, DFUs can lead to severe infections and amputations, significantly increasing healthcare costs and decreasing quality of life. The advanced solution is a smart prosthetic sock fitted with pressure and temperature sensors that constantly monitor foot health indicators linked to DFUs. The data collected is analyzed via a microcontroller and sent wirelessly to a mobile app or cloud, where machine learning algorithms detect early deterrent signs. This enables real-time alerts and improved self-care. The sock's wearable, non-invasive design enhances patient adherence and allows for remote monitoring by healthcare providers. It's ability to continuously track foot health, compared to traditional periodic checkups, enables early interventions, reducing hospitalizations, pain, and medical expenses. All in all, this project provides a current,patient-friendly approach to DFU prevention, combining advanced sensors with real-time data analytics. Future developments aim to enhance sensor accuracy, refine data processing, and validate the technology through clinical trials, making it a promising tool for enhancing diabetic foot care and saving lives.**

Keywords—diabetes, foot ulcers, sensors, smart sock.

Received: 02-12-2025 Accepted: 08-01-2026 Published: 15-01-2026

INTRODUCTION

Diabetic foot ulcers (DFUs) represent a significant and growing challenge in the management of diabetes, affecting millions of individuals worldwide. As the global prevalence of diabetes continues to rise, projected to reach **700 million** cases by **2045** according to the International Diabetes Federation, the incidence of DFUs is expected to increase correspondingly. These ulcers are not merely a minor inconvenience; they are a serious complication that can lead to severe health consequences, including chronic infections, prolonged hospital stays, and even limb amputations. The emotional and psychological toll on patients, coupled with the financial burden on healthcare systems, underscores the urgent need for effective preventive and management strategies.

The **pathophysiology** of DFUs is primarily associated with peripheral neuropathy, a condition that decreases sensation in the feet. This loss of protective sensation can result in patients being unaware of minor injuries, blisters, or infections, which can escalate into more serious complications if left untreated. Furthermore, factors such as poor circulation, foot deformities, and inadequate foot care practices exacerbate the risk of ulceration. Consequently, the management of DFUs requires a multifaceted approach that includes patient education, regular foot examinations, and timely interventions.

In recent years, advancements in wearable technology have opened new avenues for monitoring and managing foot health in individuals with diabetes. **Smart socks and insoles** equipped with **sensors** have emerged as innovative tools that can provide real-time data on critical parameters such as **plantar pressure** and **temperature**. These metrics are essential for identifying areas of increased risk for ulceration, allowing proactive measures to be taken before a wound develops. For instance, elevated temperature readings may indicate the onset of an infection, while abnormal pressure patterns can signal the need for adjustments in footwear or gait.

The integration of these technologies into a prosthetic sock represents a novel and promising approach to the early detection of DFUs. By combining the benefits of smart textiles with the functionality of prosthetics, this project aims to create a comprehensive solution that not only enhances foot health monitoring but also improves the overall quality of life for individuals with diabetes. The prosthetic sock would be designed to seamlessly incorporate sensors that continuously track foot conditions, providing users with valuable insights through a connected app or device. This real-time feedback could empower patients to take charge of their foot health, facilitating timely interventions and reducing the risk of complications.

Additionally, the potential for data analytics and machine learning algorithms to analyze the collected data could result in personalized recommendations for foot care, customized to each patient's needs. This level of personalization could substantially improve the effectiveness of preventive measures, ultimately leading to better health outcomes and lower healthcare costs related to DFUs.

In conclusion, developing a smart prosthetic sock with advanced monitoring technology offers great potential to transform diabetic foot health management. By focusing on early detection and intervention, this project seeks to reduce DFU risks, improve outcomes, and enhance the quality of life for people with diabetes. Moving forward, collaboration among healthcare professionals, engineers, and patients will be crucial to ensure that this innovative solution meets user needs and effectively tackles the challenges of diabetic foot ulcers.

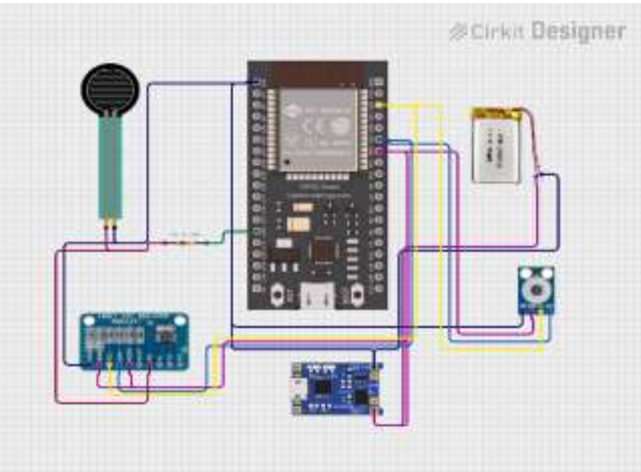

Fig 1

Fig 1.1

METHODOLOGY:

The process of creating the smart prosthetic sock is systematic and multi-faceted, including design, fabrication, integration of sensors, data acquisition and analysis, and user testing. All these are important steps to ensure that the end product is effective, user-friendly, and able to cater to the needs of people with diabetes.

1**. Design and Fabrication**

- **3D Printing Technology** (If Possible**)**: The first part of the project will involve designing the sock through the use of advanced 3D printing technology. This process enables the production of highly customized and complex designs that can fit the individual anatomical characteristics of each user's foot. 3D printing ensures a perfect fit, improving comfort and tracking efficiency.

- **Material Selection**: For improved comfort, hygiene, and skin health, the sock will be made from a blend of stretchy, breathable, and moisture-wicking materials like nylon, spandex, and antimicrobial fabrics. Thoughtful material selection with consideration for differing thicknesses will enhance cushioning at pressure points, ensuring durability and a fresh feel. **Prototyping**: The first prototypes will be made to assess the comfort and fit of the sock. Prototypes will be iteratively tested and modified to meet diabetic patients' ergonomic needs.

2. **Sensor Integration**

- **Choice of Sensors**: The sock will have a variety of sensors to track vital parameters of foot health. Major sensors will include:

- **Pressure Sensors**: Pressure sensors will be located strategically along the sock to capture plantar pressure distribution. Anomalies in pressure patterns are detected, triggering the sock to detect areas at risk of ulceration where early intervention can occur.

- **Temperature Sensors**: Temperature sensors will be embedded to capture fluctuations in temperature among various regions of the foot. Increased temperatures point to inflammation or infection, thus serving as an early warning mechanism for complications.

- **Sensor Placement and Calibration**: Sensor placement will be deliberately planned to gain the best coverage and accuracy. Calibration procedures will be put in place to guarantee that the sensors read reliably and consistently. This could mean testing the sensors under different conditions so that ambient temperature and humidity are factors considered.

3. **Data Collection and Analysis**

- **Real-Time Data Monitoring**: The combined sensors will constantly monitor pressure and temperature data throughout normal activities. This real-time data monitoring will offer insight into the user's foot health and detect early signs of issues before they become a problem.

- **Wireless Transmission of Data**: The data gathered will be wirelessly transmitted to a mobile app using Bluetooth or any other secure communication protocol. This will enable users to view their foot health data at their convenience on smartphone or tablet devices.

- **Machine Learning-based Data Analysis**: The mobile app will use machine learning algorithms to process the received data. Identifying trends and patterns related to possible infections or ulceration hazards, the app can inform users with relevant information and notifications. The algorithms will be taught on past data so that their precision and predictability will increase over time.

4. **User Testing**

- **Cohort Selection**: A representative group of diabetic patients will be hired for user testing to assess the smart prosthetic sock's performance. This sample will consist of patients with differing levels of diabetes-related complications so that the sock can be tested over a wide range of needs.

- **Effectiveness Assessment**: Patients will wear the sock for an assigned duration of time, collecting data on the performance of the sock in warning early infection and ulceration signs. The success of the sock will be judged by how promptly it alerts, as well as whether the readings made by the sock are accurate or not.

- **Feedback Gathering and Revision**: During the testing period, user comments will be collected in the form of surveys and interviews. Volunteers will be requested to comment on their experiences as per comfort, usability, and the value experienced with the information shared by the sock. Feedback will play a vital role in redesigning the sock and its functions to satisfy the users.

- **Final Refinements**: With the information obtained from user testing, final refinements will be made to the design of the sock, sensor positioning, and algorithms for data analysis. This cycle of improvement will ensure that the final product is effective in tracking foot health as well as comfortable enough for everyday use.

Fig 2

Key Points

1. The Growing Problem of Diabetic Foot Ulcers (DFUs)

- DFUs affect nearly **25% of people with diabetes** at some point in their lives.
- If left untreated, **85% of DFUs lead to lower limb amputations**.
- Diabetes-related amputations **reduce life expectancy**, with nearly **50% of patients dying within five years** post-amputation.
- **Insight:** Preventing DFUs through **early detection** can significantly reduce mortality, healthcare costs, and improve patients' quality of life.

2. Challenges in Existing DFU Detection & Monitoring

- DFUs develop due to **neuropathy (loss of sensation), poor circulation, and excessive pressure** on specific foot areas.
- Current detection methods (visual inspections, doctor visits) **are reactive rather than proactive**, leading to late-stage diagnosis.
- Wearable technology has shown potential, but existing smart insoles and monitoring devices are often **expensive, bulky, or uncomfortable**.
- **Insight:** A **smart prosthetic sock** can offer **continuous, non-invasive monitoring** in a more **comfortable and accessible** way.

3. Importance of Real-Time Monitoring for Early Detection

- Research shows that **sustained pressure on a specific foot area for just 30 minutes can cause tissue damage**.

- An increase in local foot temperature greater than **2°C** may signal early inflammation and potential ulcer formation.
- If DFUs are detected early, **the risk of amputation decreases by over 50%**.
- A real-time sensing system can **immediately detect pressure and temperature anomalies**, allowing **early intervention before an ulcer forms**.

4. How the Smart Prosthetic Sock Solves These Challenges

- The sock is embedded with **pressure and temperature sensors** to **continuously monitor** foot health.
- Data is transmitted via **Bluetooth/Wi-Fi** to a mobile app for **real-time alerts and historical tracking**.
- Machine learning algorithms analyze sensor data to **predict ulcer formation risk**.
- The sock is designed to be **lightweight, washable, and comfortable for daily wear**.
- By integrating **wearable technology, AI, and IoT**, this solution **bridges the gap between self-monitoring and medical diagnosis**, helping diabetic patients take **preventive action before complications arise**.

5. Long-Term Impact & Future Potential

- Over **463 million people worldwide have diabetes**, and this number is projected to rise to **700 million by 2045**.
- The global diabetic foot ulcer treatment market is expected to exceed **$13 billion by 2028**.
- Current foot monitoring solutions are mostly **clinic-based or expensive**, limiting accessibility.
- A low-cost, **scalable** wearable device can have **a massive global impact**, reducing healthcare costs and **improving the quality of life** for millions of diabetic patients.

CONCLUSION

The creation of the **smart prosthetic sock** is a milestone in diabetic foot health management, fulfilling an essential requirement for **effective monitoring and early diagnosis of diabetic foot ulcers (DFUs)**. With the increase in diabetes incidence worldwide, complications, especially DFUs, constitute a significant burden on individuals and healthcare systems. By harnessing **cutting-edge wearable tech** into a prosthetic sock, this project seeks to empower people with diabetes to **proactively manage their foot health**.

In summary, the **intelligent prosthetic sock** is capable of changing the manner in which diabetic foot health is assessed and treated. With its **user-friendly solution** integrating comfort, technology, and patient-specific care, this project promises to drastically curb the occurrence of DFUs, enhance patient recovery, and improve the overall quality of life of those with diabetes. As we look to the future, we hope that our research will add to the larger body of work in diabetes care and motivate further developments that meet the needs of this population. Through collaboration with clinicians, engineers, and patients, we hope that this project will lead to a future where diabetic foot complications are prevented and treated effectively, resulting in healthier lives for millions.

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