

Instrumented Insole for Plantar Pressure Monitoring Using Integrated Architecture and Web Platform

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Abstract

Instrumented insoles are increasingly utilized for plantar pressure analysis in gait studies, biomechanics, and the advancement of wearable sensing technologies. However, many academic prototypes primarily emphasize signal acquisition, often neglecting aspects such as data traceability, historical record management, user-specific calibration, and web-based visualization. Furthermore, the restoration and reuse of previously developed devices have received limited attention, despite their potential to enhance the longevity and utility of research prototypes. This study details the restoration and integration of a piezoresistive instrumented insole featuring embedded data acquisition and wireless communication, supported by a database and a web platform for visualization and descriptive analysis. The primary objective was to recover an existing prototype and transform its measurements into organized, traceable, and reusable records for research purposes. The proposed system is designed solely as a research tool and does not provide clinical diagnosis. The methodology consisted of four stages: hardware diagnosis and restoration, embedded system stabilization, web platform development, and validation through controlled experiments. A device was successfully restored to an operational state with a wireless connection that transmits the measured data to a local server. The measurements were associated with individual user profiles, stored in a structured database, and made available for subsequent medical review. A complete array of sensors is presented as a heat map on the web interface to facilitate the interpretation of plantar pressure distribution. The prototype will undergo future clinical validation; however, repeatability showed 95% similarity between measurements, and static response showed 94% stability.

Keywords

Plantar pressure, Instrumented insole, Piezoresistive sensors, Embedded systems, Wireless telemetry, Web platform, Personalized calibration

1. Introduction

Plantar pressure measurement makes it possible to observe the load distribution between the foot and support surface. This information is valuable for gait analysis, balance assessment, footwear design, ergonomic evaluation, and the development of bioinstrumentation systems. Although commercial pressure platforms provide high measurement accuracy, their cost, limited portability, and dependence on controlled laboratory environments often restrict their use in academic projects with limited resources. Instrumented insoles have emerged as an attractive alternative because they enable pressure measurements under everyday conditions while offering a compact and wearable solution for data collection [1, 2, 3].

Recent advances in flexible sensing materials, embedded electronics, wireless communication, and web technologies have considerably expanded the capabilities of these systems. Current research reports applications ranging from gait assessment and activity recognition to rehabilitation support and machine-learning-based classification [2, 3, 4, 5]. However, achieving reliable long-term operation remains challenging. Issues such as sensor repeatability, power consumption, user comfort, individualized calibration, communication reliability, and effective data management continue to affect system

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performance. Consequently, research has progressively shifted from developing isolated sensing devices toward integrated platforms capable of acquiring, storing, visualizing, and analyzing plantar pressure data. This evolution reflects the transition from stationary laboratory equipment to wearable systems that combine sensing, wireless communication, and software services within a single ecosystem.

Almuted et al. identified applications of these technologies in healthcare, sports, gait analysis, rehabilitation, and activity recognition, while also highlighting challenges related to energy autonomy, user comfort, mechanical integration, and data processing [2]. Similarly, Santos et al. reported that the overall performance of instrumented insoles depends not only on the sensing element but also on sensor placement, signal conditioning, sampling strategy, calibration, and data processing [3]. In a subsequent review, the same authors emphasized that developing an effective smart insole requires simultaneously addressing ergonomic, energy, connectivity, cost, and validation constraints [4].

These studies indicate that the value of an instrumented insole extends well beyond its sensing elements. The usefulness of these systems increasingly depends on how effectively sensing, data acquisition, wireless communication, storage, visualization, and analysis are integrated into a unified workflow. When one of these components is absent, a prototype may still demonstrate its sensing capability, but its potential for long-term studies and meaningful comparisons between experimental sessions is considerably reduced. Consequently, recent research has focused on complete measurement platforms rather than standalone sensing devices, particularly for applications involving longitudinal monitoring, user-specific calibration, and comparative analyses across multiple sessions.

Within the Colombian academic community, several studies have demonstrated the feasibility of developing instrumented systems for plantar pressure analysis. Camargo et al. proposed a platform for plantar pressure measurement, while Barragán Moreno developed an active insole designed to detect inadequate foot posture during the stance phase of gait [1, 6]. These contributions illustrate the potential of locally developed solutions while also revealing a common limitation in academic research: many prototypes cease to evolve once the original project has concluded.

For this reason, restoring and extending existing devices becomes as important as designing new ones. Functional recovery involves more than repairing hardware; it also requires updating embedded software, improving communication reliability, documenting system behavior, and incorporating mechanisms for structured data storage and analysis. Although calibration, filtering, and experimental validation improve measurement quality, they do not ensure that a prototype will remain useful over time. Long-term continuity depends on maintaining both the operational integrity of the hardware and a data management strategy that allows measurements to be organized, retrieved, and compared efficiently.

Motivated by these challenges, this work focuses on the functional recovery and integration of an existing instrumented insole originally developed at the Facultad Tecnológica of the Universidad Distrital Francisco José de Caldas and reported by Barragán Moreno [6]. Instead of proposing a completely new design, the study extends the capabilities of the original prototype through embedded system stabilization, wireless communication, structured data storage, personalized calibration, and a web-based platform for visualization and analysis. Table 1 summarizes the relationship between previous studies and the proposed approach, highlighting that few academic developments combine hardware restoration, telemetry, historical data management, personalized calibration, and experimental validation within a single platform.

The literature consistently suggests that the most effective systems are those that establish a coherent connection between sensing, calibration, communication, storage, visualization, and validation. Guided by this perspective, the functional recovery carried out in this work is considered an essential stage of the research rather than a simple hardware repair. Restoring the prototype provides the foundation for evaluating its reliability and extending its capabilities within a modern embedded and web-based architecture.

The proposed system is intended exclusively for academic research and should not be interpreted as a certified medical device or a clinical diagnostic instrument. Its main contribution is the integration of a complete and traceable workflow that includes wireless data transmission, user and session management, individualized calibration, historical data storage, and descriptive analysis of plantar

pressure according to different support regions. Based on this objective, the study addresses the following research question: How can an existing instrumented insole be functionally restored and integrated with embedded electronics and a web platform to acquire, organize, and analyze plantar pressure data in a structured and reusable manner for research applications?

Table 1

Summary of the relationship between the proposed system and existing approaches.

Reference	Focus	Contribution to the field	Relationship with the proposal
Almuted et al. [2]	Review of smart insoles	Identifies applications, potential, and challenges related to comfort, energy, and integration.	Justifies addressing the insole as a complete system and not only as a sensor.
Santos et al. [3]	Review of sensor technologies	Highlights criteria for sensor selection, placement, and processing.	Supports the need for the calibration and stabilization of readings.
Santos et al. [4]	Review of prototypes and optimization pathways	Presents trends in design, validation, and optimization.	Supports a modular and iterative approach.
Rathke et al. [7]	IoT-based wireless system	Integrates sensing, communication, and kinetic monitoring.	Reinforces the use of transmission and data structure.
Alegria et al. [8]	Wireless insole for locomotion	Reports pressure monitoring with storage.	Supports the migration from local reading to persistence.
Agrawal et al. [5]	Statistical analysis and machine learning	Shows the use of plantar data for assisted classification.	Defines the scope: basic analysis, not autonomous diagnosis.
Fuchs et al. [9]	Accuracy with a reduced sensor set	Reports usable accuracy from a simplified configuration.	Supports prioritizing the quality of the data flow over the addition of hardware.

2. Theoretical Framework

2.1. Plantar Sensing and Instrumentation Criteria

Plantar pressure describes how the force exerted by the body is distributed across the different anatomical regions of the foot, including the heel, midfoot, metatarsals, and toes. Its analysis provides valuable information about weight-bearing patterns, the trajectory of the center of pressure, and the mechanical changes that occur throughout the gait cycle [1, 10]. Instrumented insoles capture this information using discrete sensing elements or sensor arrays distributed along the plantar surface. Consequently, the spatial resolution of the measurements depends on the number of sensors and their location within the insole. Although increasing sensor density can improve the representation of plantar loading, it also introduces practical trade-offs, including higher power consumption, greater wiring complexity, increased susceptibility to noise, higher manufacturing costs, and additional processing requirements.

Figure 1 illustrates the anatomical regions commonly considered in plantar pressure analysis. These reference zones facilitate the interpretation of pressure distribution and are particularly useful for distinguishing the forefoot, midfoot, heel, and toes during descriptive assessments.

According to Fuchs et al., reliable estimation of variables such as the center of pressure can be achieved even with a limited number of sensors, provided that their placement is carefully planned and aligned with the intended application [9]. Therefore, the performance of an instrumented insole is not determined solely by the number of sensing elements. In academic prototypes, a simpler sensor configuration may offer a better balance between measurement quality, calibration effort, reliability, and long-term repeatability.

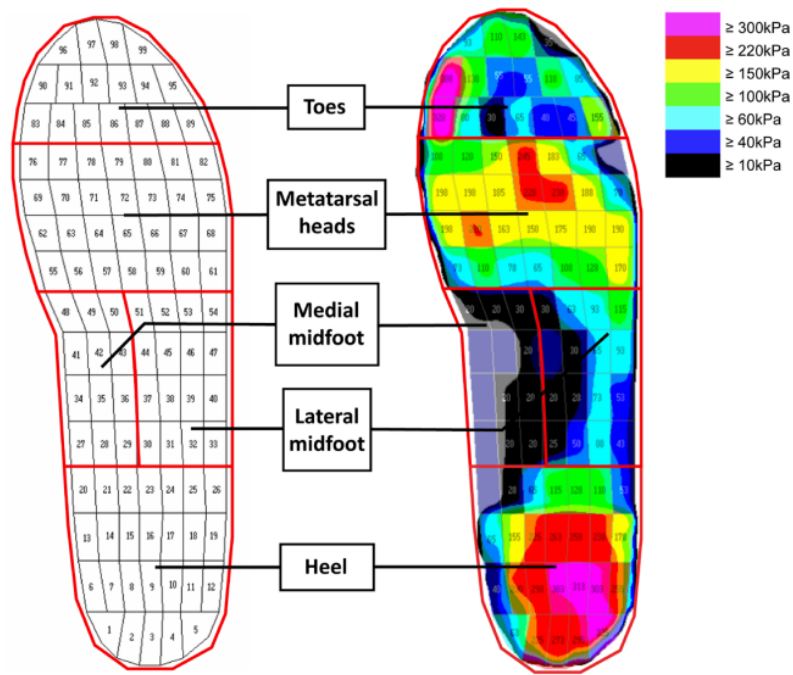


Figure 1: Anatomical zones of the sole of the foot and general distribution of plantar pressure. Adapted from [11].

2.2. Indicators by Plantar Zone

The foot sole can be organized by functional zones: heel, midfoot, metatarsals, and forefoot/toes. This division reduces matrix complexity and makes it possible to build understandable indicators. For each zone z with a set of sensors S_z , the normalized average is proposed as:

$$P_z = \frac{1}{|S_z|} \sum_{i \in S_z} x_{norm,i}. \quad (1)$$

The maximum value by zone, the difference between anterior and posterior regions, the comparison between both feet, and the variation between sessions can also be calculated. These indicators do not have a diagnostic purpose; their function is to describe system behavior and support comparisons in applied research. The information can be presented through pressure maps with a relative scale, time plots, and session summary tables, following the zone-based representation of the plantar surface shown in Figure 1, which corresponds to the regional division adopted by Zhang et al. for the analysis of peak pressure and pressure–time integral in dynamic conditions [11]. Reliable visualization and useful indicators depend in turn on a sensing technology that stays stable and repeatable under different loads.

2.3. Piezoresistive Sensing and Signal Conditioning

Piezoresistive sensors are widely used in low-cost plantar pressure measurement systems because they are flexible, inexpensive, and can be readily integrated with embedded electronic platforms. Their operating principle is based on the variation of electrical resistance in response to an applied mechanical load, allowing pressure to be converted into an electrical signal that can be acquired and processed. Despite these advantages, their performance is influenced by factors such as hysteresis, signal drift, temperature variations, material properties, and manufacturing variability, making individual sensor calibration an essential step for obtaining consistent measurements [3, 12]. For this reason, the signals generated by these sensors generally require conditioning, filtering, and normalization before they can be interpreted or compared across different measurement sessions.

Figure 2 illustrates the operating principle of a piezoresistive sensor integrated into an instrumented insole. As pressure is applied to the plantar surface, the electrical resistance of the sensing material changes proportionally, producing a measurable signal that reflects the load distribution beneath the foot.

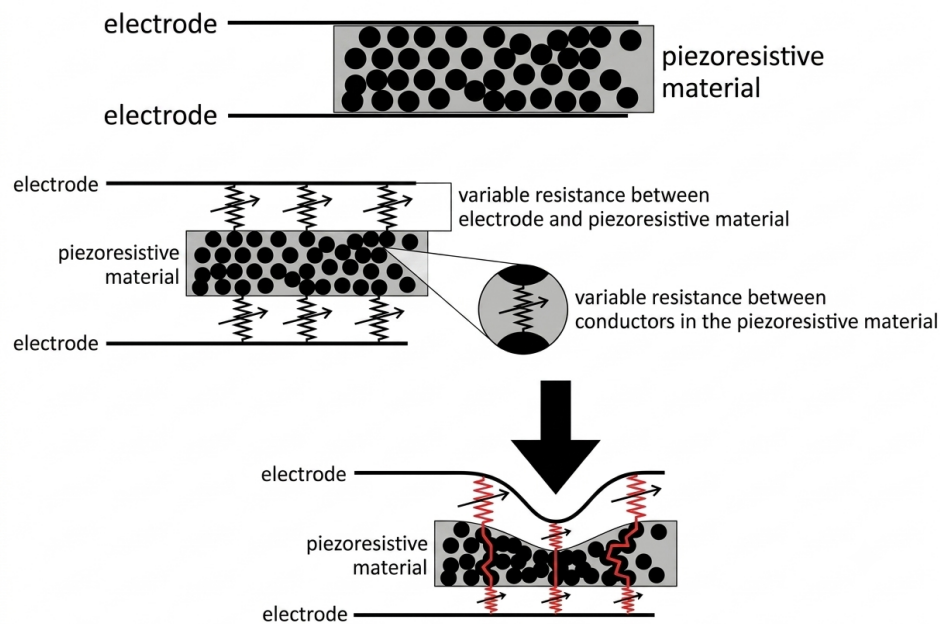


Figure 2: General scheme of the operating principle of a piezoresistive sensor in an instrumented insole [12].

2.4. Wireless Communication and Connected Architectures

Wireless communication has significantly expanded the capabilities of instrumented insoles by enabling data transmission beyond the sensing device itself. While real-time local visualization provides immediate access to pressure measurements, it does not address essential aspects such as long-term storage, comparison of multiple sessions, or remote access to collected data. To overcome these limitations, recent studies have incorporated communication technologies into plantar pressure monitoring systems. For example, Rathke et al. developed an IoT platform for monitoring gait kinetics during therapeutic interventions using pressure sensors and an embedded controller [7]. Similarly, Alegría et al. proposed a wireless insole capable of acquiring and storing plantar pressure data during human locomotion, illustrating the ongoing transition from standalone prototypes to connected measurement platforms [8].

Selecting an appropriate wireless technology involves balancing several design requirements rather than simply choosing an available communication module. Factors such as communication range, power consumption, latency, data throughput, security, and compatibility with the target application all influence this decision. WiFi is particularly suitable when direct communication with local servers or web-based services is required, whereas Bluetooth Low Energy (BLE) offers lower energy consumption and is better suited for portable applications that rely on smartphones or gateway devices [13]. In research prototypes, separating data acquisition, communication, and storage into independent layers also facilitates future modifications without affecting the overall system architecture.

Reliable communication is equally important for preserving data integrity. Packet loss, temporary disconnections, synchronization errors, or incorrect associations between users and measurement sessions can compromise the quality of the recorded information, even when the sensing hardware performs correctly. For this reason, the proposed architecture incorporates a session management strategy that links every measurement to the corresponding user, acquisition time, calibration parameters,

and transmission status, ensuring that the collected data remain organized, traceable, and suitable for subsequent analysis.

2.5. Analytics, Databases, and Web Platforms

The value of plantar pressure measurements depends not only on their acquisition but also on how the resulting data are organized, stored, and interpreted. As instrumented insoles have evolved, increasing attention has been given to analytical methods that transform raw sensor readings into meaningful information. Recent studies have explored statistical techniques, signal processing, and machine learning for this purpose. Agrawal et al., for example, compared statistical and machine learning approaches to distinguish between healthy and diabetic feet, emphasizing that such predictive models require rigorous clinical validation before they can support medical decision-making [5]. Other notable contributions include the wearable system proposed by Tang et al. for measuring plantar pressure and shear forces in people with diabetes, the deep learning framework developed by Tian et al. for foot health assessment, and the biomechanical analysis presented by Kasai et al. for individuals with flatfoot [14, 15, 16]. Although these studies demonstrate the growing capabilities of intelligent plantar pressure systems, their clinical conclusions rely on specific medical protocols and ethical approval.

In contrast, research-oriented platforms not intended for clinical diagnosis should focus on descriptive analyses that characterize system performance without making medical interpretations. Indicators such as pressure distribution by anatomical region, normalized peak pressure, average pressure values, bilateral load differences, temporal support patterns, variations across measurement sessions, and signal stability provide valuable information for evaluating both the prototype and the acquired data. These metrics are useful for understanding plantar loading behavior and assessing measurement consistency, but they should not be interpreted as diagnostic outcomes.

The organization and accessibility of these measurements are equally important. A web-based platform offers clear advantages over standalone local applications by centralizing information, maintaining historical records, managing user profiles, and simplifying data retrieval and export. It also enables different levels of access, allowing researchers to examine complete datasets and system metrics while providing participants with a simplified view of their recorded measurements. Following this approach, the proposed system integrates an application programming interface (API) for data reception, a relational database for structured storage, and a web interface for visualization and consultation. MySQL was selected as the database management system because it provides a robust environment for organizing measurement records, preserving session traceability, and supporting long-term data management [17].

2.6. Calibration

The response of an instrumented insole is influenced by several factors, including body weight, posture, foot morphology, weight distribution, sensor placement, and the intrinsic characteristics of the sensing material. As a result, raw measurements obtained from different users—or even from the same user under different conditions—are not directly comparable. For this reason, a calibration procedure is required to establish reference values for each user or measurement session, allowing the acquired data to be expressed on a normalized scale.

A commonly used normalization approach is given by

$$x_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}}, \quad (2)$$

where x_i represents the instantaneous reading of a sensor or anatomical region, x_{min} corresponds to the minimum reference value, and x_{max} is the maximum value obtained during calibration. If $x_{max} = x_{min}$, the normalization cannot be performed because it would result in division by zero. In such cases, the corresponding sensor is flagged as uncalibrated or invalid for that measurement session. Although this normalization method is straightforward, it provides an effective way to compare pressure distribution patterns across different sessions without attempting to estimate absolute pressure values.

Beyond numerical scaling, calibration also documents the conditions under which the measurements are acquired. Information such as the participant's posture, support duration, evaluated foot, footwear condition, contact surface, and any relevant observations helps place each dataset in context and facilitates comparisons between sessions. This approach makes it possible to distinguish changes associated with the participant from those introduced by the experimental setup. Future developments may incorporate calibration using reference loads, sensor-specific adjustments, nonlinear compensation models, or drift correction techniques, although these approaches require a more detailed characterization of the sensing material.

3. Methodology

This work followed an applied research methodology with experimental validation, structured into four phases: diagnosis and functional recovery, embedded system stabilization, web platform development, and system validation. Figure 3 summarizes the proposed workflow.

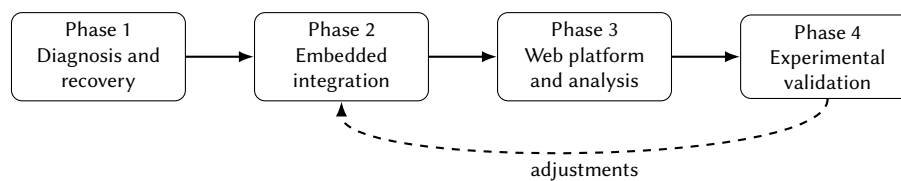


Figure 3: The methodological phases proposed for recovery and integration.

The study was based on the recovery of a piezoresistive instrumented insole developed at the Facultad Tecnológica of the Universidad Distrital Francisco José De Caldas and reported by Barragán Moreno [6]. Originally designed to detect incorrect foot postures during the stance phase of gait, the prototype was no longer operational at the beginning of this research.

The recovered device was integrated into an academic platform for plantar pressure monitoring. Its function was to acquire sensor readings, transmit them to the software layer, store the information with session traceability, and display the results through a web interface. The scope of this work was limited to functional validation and descriptive analysis under controlled conditions; clinical diagnosis, disease classification, and the replacement of certified medical devices were beyond the objectives of the study.

The general working sequence was organized in three stages. First, a physical and electronic review of the device was carried out, which covered connection continuity, condition of the sensitive material, electrode behavior, power supply, analog reading, and stability at the measurement points. Then, the matrix values were acquired by the embedded module, basic filtering was applied, data packets were structured, and the information was transmitted wirelessly. Finally, the records were received by the web layer, associated with a user and a session, normalized, and displayed as indicators.

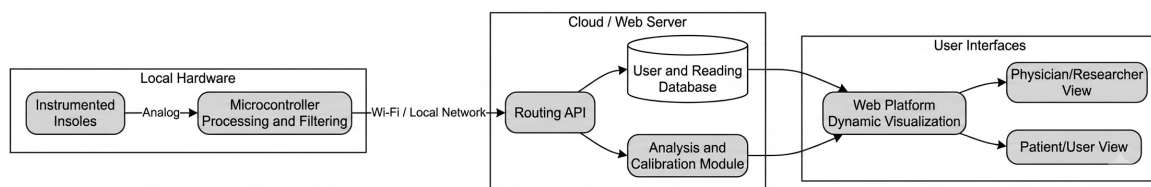


Figure 4: Block diagram of the proposed solution.

A layered architecture was adopted, as shown in Figure 4. The first layer corresponded to the local hardware, integrated by the insole and the microcontroller. The second was responsible for communication and the API, so that physical acquisition was not coupled to the interface. The third

organized the information in a database and incorporated the calibration module. Finally, the web platform presented the data according to the consultation profile.

The system requirements were grouped into seven dimensions: functional recovery, embedded acquisition, communication, persistence, calibration, web interface, and data security. Each dimension and its corresponding verification criterion are summarized in Table 2. A single technology was not fixed from the outset; instead, a selection guide was established to evaluate options such as ESP32, Arduino Nano 33 IoT, STM32, or other microcontrollers with analog reading and either direct connectivity or connectivity through external modules, according to their datasheets [18, 19, 20].

Table 2

Functional and technical requirements of the solution.

Dimension	Requirement	Verification criterion
Functional recovery	Restore pressure point readings and connection continuity	Response test under known load and log of corrected failures
Embedded acquisition	Read sensor matrix, filter basic noise, and structure packets	Comparison between repeated readings under controlled conditions
Communication	Transmit data via WiFi or BLE without critical session loss	Record of received packets, incomplete packets, and reconnection
Persistence	Associate each measurement with user, session, date, time, and calibration	Historical consultation from database and session export
Calibration	Normalize values by user and reference session	Reproducible application of minimum and maximum parameters
Web interface	Display maps, curves, and indicators by plantar zone	Functional review of the research panel and simplified view
Data security	Use consent, coding, and access control	Completed forms and minimum roles in the platform

3.1. Phase 1: Diagnosis and Functional Recovery

In the first phase, the actual state of the prototype was established. The physical structure of the insole, the conductor continuity, the connectors, the power supply, the sensitive material, the conditioning stage, and the initial reading were reviewed. Each failure was documented in order to ensure the traceability of the process. Minimum operating criteria were also defined, such as the response to an applied load, the basic stability, the operating range, the tentative sampling frequency, and the compatibility with the microcontroller. Sensing points with an irregular response were flagged in the record, which prevented a hardware failure from being read as a real change in plantar pressure.

3.2. Phase 2: Embedded Stabilization and Integration

During the second phase, the recovered insole was integrated with the embedded system. The firmware was developed to acquire sensor readings, perform basic signal filtering, organize the data into transmission packets, manage measurement sessions, and send the information to the software platform. To facilitate development and maintenance, the software was organized into independent modules for data acquisition, filtering, communication, and diagnostics. This modular structure simplified testing and prevented changes in the web application from affecting the acquisition process.

Signal preprocessing included a moving average filter, the removal of out-of-range readings, and the detection of inactive sensors. Each transmitted packet was associated with a session identifier and either a timestamp or a sample counter, allowing the original acquisition sequence to be reconstructed on the server. The communication protocol was intentionally kept simple while ensuring reliable data transmission and preserving the traceability of each measurement.

3.3. Phase 3: Web Platform and Analysis Module

The third phase focused on developing the software platform. A backend was implemented in Python and integrated with a relational database, while the user interface was developed using HTML, CSS, and JavaScript. The backend was responsible for receiving the data packets transmitted by the embedded system, verifying their integrity, storing the acquired measurements, and calculating the normalized indicators. The database was structured to manage users, sessions, calibrations, sensor readings, and test observations.

To ensure data traceability, the platform incorporated a session start function. Each time a new acquisition began, the system generated or activated a record containing the session identifier, user information, date, time, prototype configuration, and calibration settings. This allowed every measurement to be associated with its corresponding acquisition context.

The web platform was designed with two access levels. The research view provided complete access to measurement records, historical data, calculated indicators, and export functions, whereas the participant view presented the results through simple graphs and an easy-to-understand interface. This separation allowed each type of user to access information appropriate to their role without exposing unnecessary technical details.

3.4. Phase 4: Experimental Validation

The system was validated through controlled tests conducted with adult volunteers in an academic setting. Before each trial, participants were informed about the purpose and scope of the study, provided their informed consent, and were assigned anonymous identification codes to protect their privacy. The evaluation included static bipedal stance, assisted single-leg support, weight-shifting exercises, and short walking trials under controlled conditions.

A convenience sample was selected because the objective was to verify the functional integration of the proposed platform rather than to perform a clinical evaluation. The collected data were analyzed using descriptive statistics, including mean, maximum, minimum, and standard deviation values, together with comparisons between plantar regions and measurement sessions. In addition, technical aspects such as communication interruptions, inactive sensors, and data storage performance were monitored to identify opportunities for improving both the hardware and software. The instruments used during the validation process and their relationship to each project phase are summarized in Table 3. The results of this validation demonstrate the operational performance of the integrated system and should not be interpreted as clinical or medical evidence.

Table 3
Experimental validation plan for the integrated system.

Test	Purpose	Expected evidence	Acceptance criterion
Static response	Verify reading under controlled support	Stable time series by zone	Variation within the range defined by the team
Repeatability	Compare sessions under similar conditions	Averages and deviations by sensor/zone	Explainable differences and no erratic sensors
Transmission	Evaluate packet reception	Count of sent and received samples	Low loss or loss identified by the platform
Calibration	Check normalization by user	Reference parameters and normalized values	Recoverable session associated with user
Interface	Verify the usage flow	Start, consultation, and export record	Operation without ambiguous steps
Basic usability	Collect user perception	Short survey and observations	Documented adjustments for a new iteration

4. Results

The evidence obtained during the tests is presented below according to the requirement dimensions defined in Table 2, following the order of the data flow: functional recovery, embedded acquisition, communication, persistence, and web interface.

The first phase produced an operational insole under controlled conditions, together with a technical diagnosis that indicated which components were recovered, which ones were replaced, and which restrictions persisted. The sensing points that showed an irregular response were flagged in the record, so that hardware failures were not interpreted as actual variations of plantar pressure. Once the operational status of the device had been verified, the recovered insole was used as the basis of the integrated platform, and the acquisition, communication, storage, and visualization functionalities were incorporated on top of it. The resulting device, composed of the instrumented insole, the embedded module, and the connection harness, is shown in Figure 5.



Figure 5: Integrated prototype of the instrumented insole after functional recovery.

The static response and repeatability tests defined in Table 3 were carried out with reference masses applied directly on the recovered insole. Calibrated discs were placed on the heel, midfoot, and forefoot regions, and the load was increased in steps of 1 kg up to 6 kg per region, from the initial level shown in Figure 6 to the maximum level shown in Figure 7. Each load level was held for 30 s while the sensor matrix was sampled continuously, and the complete sequence was repeated five times, keeping the same disc placement.



Figure 6: Initial load level of the reference masses on the heel, midfoot, and forefoot regions.



Figure 7: Maximum load level of the incremental sequence of reference masses.

When the repeated sequences were compared, the readings obtained for the same load level agreed within 95%. During the sustained-load window, the average reading of the final segment differed by 6% from the initial one, so the static response remained 94% stable; this deviation is consistent with the progressive drift described for piezoresistive materials under constant load [3, 12]. Both values describe the behaviour of the prototype under controlled loads and are not indicators of clinical performance.

With respect to the embedded acquisition and the wireless link, the tests confirmed that the data were transmitted by the hardware module to the local server with high precision. A slight packet loss was documented during the initial connection setup; nevertheless, the transmission stabilized rapidly. Once stabilized, a constant and reliable data flow was maintained, and the packets were received without interruption, as evidenced by the reception logs registered on the server, which were subsequently processed by the local network without additional delays.

During the physical acquisition stage, a clear and stable sensory visualization was obtained. The readings of the sensor matrix were rendered locally as a heat map, in which each cell corresponds to a measurement point of the insole and the colour scale represents the relative pressure level. Through this representation, the changes in weight and in load distribution were correctly detected, and no dead zones that could affect the data collection were identified, as shown in Figure 8.

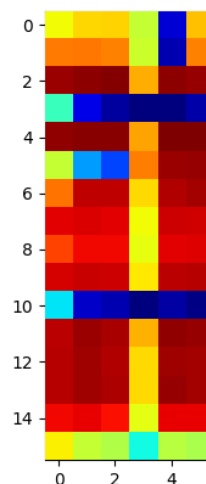


Figure 8: Local reception.

Once the physical data had been captured, the information was received and properly structured by the local server. The tests showed that a continuous, real-time flow towards the web layer was maintained, and that stable communication was achieved without significant delays or packet losses.

that could interrupt the visualization (Figure 9).

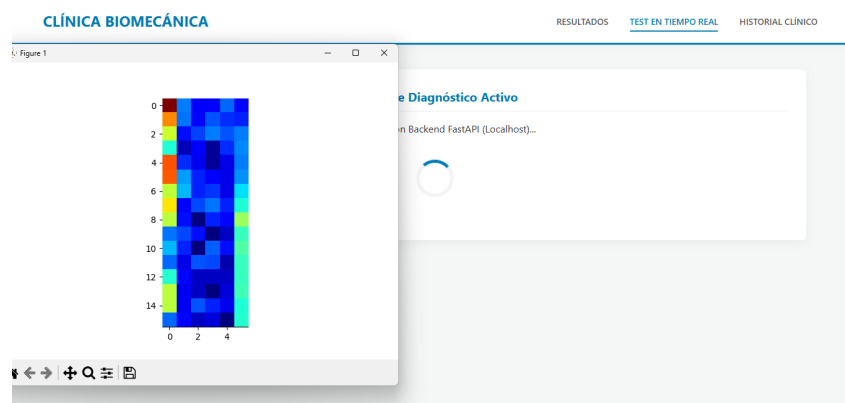


Figure 9: Acceptance Testing, API, and Web.

At the web-based graphical interface, the received information was successfully mapped. A coherent and dynamic heat map was generated, by means of which the points of highest and lowest pressure of the user's footprint were observed clearly and intuitively during the tests (Figure 10).

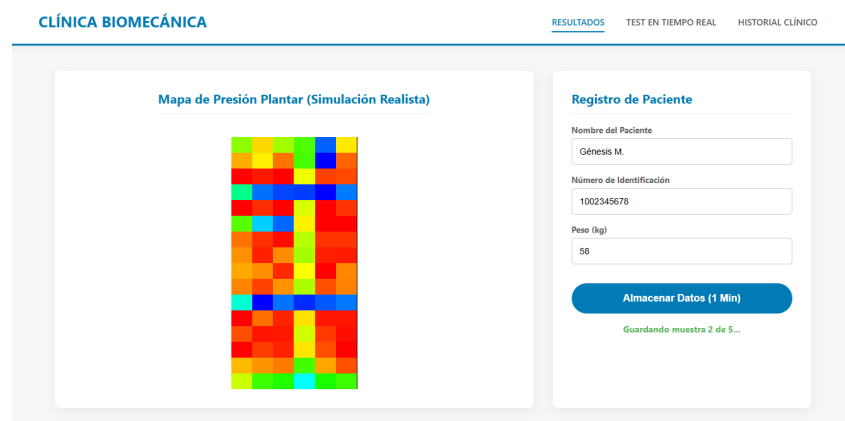


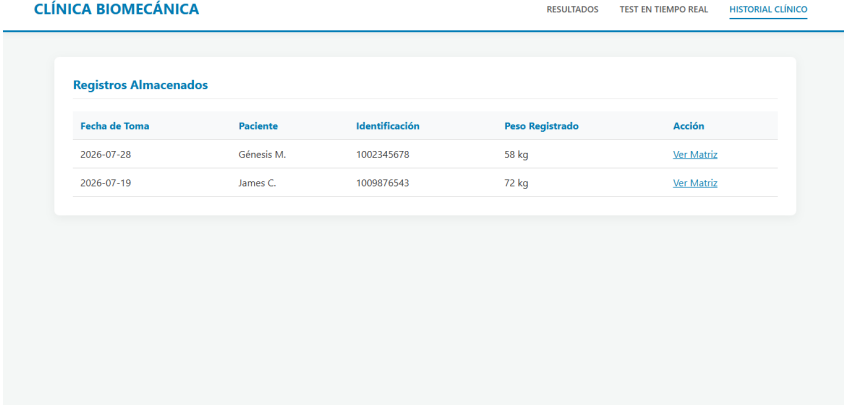
Figure 10: Testing Display and Storage Interface.

On the storage side, the database logging module operated as programmed. Temporary samples were taken within the specified timeframe and the profile of each user was correctly saved, so that all the information remained structured and available in the history of the platform, which was verified through the consultation view shown in Figure 11.

Considering the complete workflow, the integrated prototype presented in Figure 5 was verified as functional and suitable for data collection in academic settings. However, since the current design was intended for technical validation and biomechanical monitoring, its use for establishing definitive medical diagnoses was not recommended.

5. Discussion

The main contribution of this work extends beyond the development of an instrumented insole. Its value lies in integrating the complete measurement process, from data acquisition to storage and visualization, ensuring that each measurement can be associated with its corresponding user, calibration, session, and test conditions. This traceability enables comparisons between sessions and provides a structured dataset that can support future research.



The screenshot shows a web application titled 'CLÍNICA BIOMECÁNICA'. At the top right, there are three tabs: 'RESULTADOS', 'TEST EN TIEMPO REAL', and 'HISTORIAL CLÍNICO'. The 'HISTORIAL CLÍNICO' tab is active. Below the tabs, there is a section titled 'Registros Almacenados' which contains a table with the following data:

Fecha de Toma	Paciente	Identificación	Peso Registrado	Acción
2026-07-28	Génesis M.	1002345678	58 kg	Ver Matriz
2026-07-19	James C.	1009876543	72 kg	Ver Matriz

Figure 11: Web Database Inquiry.

Another relevant aspect is the functional recovery of an existing academic prototype. In university environments, many developments become unavailable once the original project is completed because of hardware failures, outdated software, or insufficient documentation. Restoring these systems requires more than repairing electronic components; it also involves verifying compatibility, documenting modifications, and ensuring that the recovered prototype can operate reliably under current conditions. This process not only extends the useful life of the device but also preserves previous research efforts and facilitates future developments.

The proposed platform is not intended to compete with commercial plantar pressure systems or certified clinical devices. Instead, it provides an integrated, low-cost solution for academic research by combining an instrumented insole, an embedded acquisition system, wireless communication, a relational database, and a web platform. The analysis performed by the system remains descriptive since clinical interpretation or automatic diagnosis would require larger datasets and specialized validation procedures.

Some limitations should be considered. The response of piezoresistive sensors may change over time, sensor placement may not fully represent the pressure distribution across the entire foot, and wireless communication may occasionally affect data continuity. In addition, the validation was carried out using a convenience sample, which limits the generalization of the results. These aspects do not compromise the feasibility of the proposed platform, but they should be considered in future improvements and broader validation studies.

The development of the system also required attention to research integrity and responsible data management. The manuscript was prepared using original text and appropriate citation of previous work, clearly distinguishing the contributions of the literature from those of the proposed platform. Likewise, participant information was handled following good practices for research data management. According to Colombian Law 1581 of 2012, personal information must be processed under the principles of consent, purpose limitation, confidentiality, and secure access [21, 22]. For this reason, participant identities were separated from the measurement records through anonymous internal codes.

Although the prototype is not a certified medical device, internationally recognized standards such as ISO 13485 and IEC 62304 provide useful guidance for software documentation, change management, and technical traceability throughout the development process [23, 24]. These standards are referenced only as good engineering practices and should not be interpreted as evidence of regulatory compliance. Any future transition toward clinical or commercial applications would require additional validation and compliance with the corresponding regulatory framework.

6. Conclusions

This work presents the functional recovery and integration of an instrumented insole for plantar pressure monitoring within an academic research platform. Its main contribution is the integration of the sensing device, embedded electronics, wireless communication, data storage, and web visualization into a single architecture that supports traceable and reusable measurements. The literature review confirms that, despite the significant advances achieved in smart insole technologies, challenges related to calibration, measurement repeatability, and data management remain open. In this context, restoring existing academic prototypes represents a practical approach to extending their usefulness and supporting future research.

The proposed architecture is structured into independent layers comprising the instrumented insole, embedded acquisition system, wireless communication, API, relational database, calibration module, and web interface. This organization facilitates system maintenance, simplifies fault identification, and ensures that every measurement is associated with its corresponding user, calibration parameters, and acquisition session. In addition, personalized calibration and the calculation of descriptive indicators by plantar region provide a consistent basis for analyzing plantar pressure data without assigning diagnostic or clinical functionality to the system.

Future work will focus on expanding the experimental validation, further characterizing the behavior of the piezoresistive sensors, evaluating alternative wireless communication technologies, strengthening data security, and building an anonymized database to support more advanced analysis methods. Any future clinical or commercial application of the proposed platform will require dedicated validation studies and compliance with the applicable regulatory framework.

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Declaration on Generative AI

During the preparation of this work, the authors used Trinka for grammar and spelling checks, and paraphrasing and rewording. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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