# Development of Foot Mat Sensor Technology for Foot Identification and BMI-Based Biomechanical Risk Prediction

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**Abstract.** This study advances the Foot Mat Sensor (FMS) technology to discern foot morphology and forecast biomechanical vulnerabilities predicated on Body Mass Index (BMI). The proposed system amalgamates the analysis of plantar pressure with various biomechanical parameters, including heel pressure, midfoot pressure, forefoot pressure, and foot contact area (FCA). Data were collected from ten participants exhibiting a spectrum of BMI, foot morphology (High Arch, Normal Arch, and Low Arch), foot length, contact area, and asymmetrical plantar pressure. The findings indicated a statistically significant correlation between elevated BMI (>25), irregular plantar pressure distribution, and heightened biomechanical risk. Participants with high BMI and Low Arch (LA) foot morphology demonstrated an augmented risk, with plantar pressure asymmetry ≥20 kPa as the principal indicator. The prediction model founded on the Random Forest algorithm attained an accuracy of 85% in categorizing biomechanical risk into low, medium, and high classifications. The Digital Footprint Scanner technology, innovated through this research, is anticipated to augment the efficacy of personalized and precise diagnostics and the prophylaxis of biomechanical injuries. This endeavor contributes to formulating a data-driven system for the early detection of biomechanical risks, with applications in medicine, athletics, and rehabilitation.

**Keywords:** Foot Mat Sensor (FMS); Biomechanics; Body Mass Index (BMI); Plantar Pressure; Risk of Injury.

## 1. Introduction

Foot biomechanics is integral to the facilitation of various quotidian human activities. The intricate anatomy of the human foot comprises 26 bones, 33 joints, and over 100 muscles, tendons, and ligaments that operate in concert to furnish support, stability, and mobility [1]. An uneven distribution of plantar pressure and constraints in the range of motion of the ankle and foot joints may constitute risk factors for the onset of overuse injuries in the foot and ankle. These biomechanical vulnerabilities are frequently shaped by individual characteristics, including Body Mass Index (BMI), foot morphology, and lifestyle choices [2]. Consequently, a comprehensive understanding of foot biomechanics is vital in the endeavor to avert injuries and enhance biomechanical efficacy [3].

BMI serves as a critical metric for comprehending an individual's weight distribution in relation to their height. An elevated BMI (>25) is typically correlated with a heightened biomechanical risk owing to the augmented load imposed on the feet, which can potentially modify the distribution of plantar pressure [4]. Prior investigations have indicated that plantar pressure measurements in individuals with elevated BMI are usually greater, particularly in the heel and forefoot regions, when juxtaposed with those possessing a normal BMI [5], [6]. This disproportionate pressure distribution may amplify the likelihood of biomechanical injuries, including plantar fasciitis and knee joint discomfort [7], [8].

In conjunction with BMI, foot morphology significantly influences body biomechanics [9]. The soles of the feet can be categorized into three principal types: High Arch (HA), Normal Arch (NA), and Low Arch (LA) [10]. Individuals exhibiting Low Arch are predisposed to irregular plantar pressure distribution, particularly within the midfoot region, which may culminate in instability and an elevated risk of biomechanical injuries [11]. Conversely, individuals with High Arch often experience increased plantar pressure in the heel and forefoot regions, representing an additional biomechanical risk factor [12].

Advancements in digital technology have facilitated novel avenues for biomechanical analysis, particularly in the assessment of foot types and the prediction of injury risk. A Digital Footprint Scanner exemplifies a technological innovation that enables precise and efficient measurement of plantar pressure. Through the utilization of plantar pressure sensors, this technology is capable of documenting pressure distribution across diverse regions of the foot, encompassing the heel, midfoot, and forefoot [13]. The resultant data can subsequently be employed to investigate the interrelations among plantar pressure distribution, BMI, and foot type, thereby allowing for a more tailored approach to biomechanical risk assessment.

The implementation of Digital Footprint Scanner technology presents numerous advantages over traditional methodologies. Firstly, this technology facilitates non-invasive measurements that are both swift and comfortable for the subjects involved [14]. Secondly, the data produced can be leveraged to formulate machine learning-based predictive algorithms, which may enhance the precision and dependability of biomechanical risk forecasting. Previous research has demonstrated that machine learning algorithms, such as Random Forest and Neural Networks, exhibit substantial potential in the analysis of biomechanical data, particularly in recognizing intricate patterns of plantar pressure distribution [13].

The objective of this study is to advance Digital Footprint Scanner technology capable of discerning foot type and forecasting biomechanical risk predicated on BMI. The emphasis of this research is on the evaluation of plantar pressure across three primary areas of the foot (heel, midfoot, and forefoot) alongside supplementary parameters, such as foot contact area (FCA) and plantar pressure asymmetry. By amalgamating this data, the biomechanical risk prediction system can furnish more individualized recommendations for the prophylaxis of biomechanical injuries.

## 2. Research methods

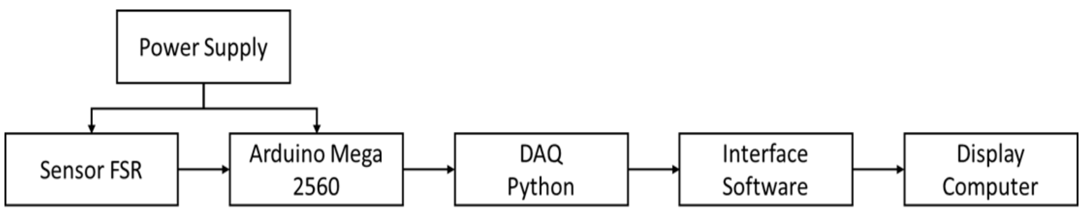
A quantitative experimental framework was employed to assess the correlation between Body Mass Index (BMI), foot morphology, plantar pressure dispersion, and associated biomechanical risk factors. The biomechanical risk forecasting model was constructed based on plantar pressure metrics obtained through the utilization of Foot Mat Sensor technology.

### *2.1. Population and Sample*

The study's target population encompassed adult participants aged between 18 and 40 years [15]. The sample comprised ten individuals selected via purposive sampling to encapsulate a spectrum of BMI classifications (low, normal, and high) and foot morphologies (High Arch, Normal Arch, and Low Arch) [16]. The inclusion criteria mandated that participants possessed no prior history of foot-related injuries or biomechanical anomalies [17]. Demographic variables of the subjects, including age, gender, height, weight, and foot length, were systematically documented [18].

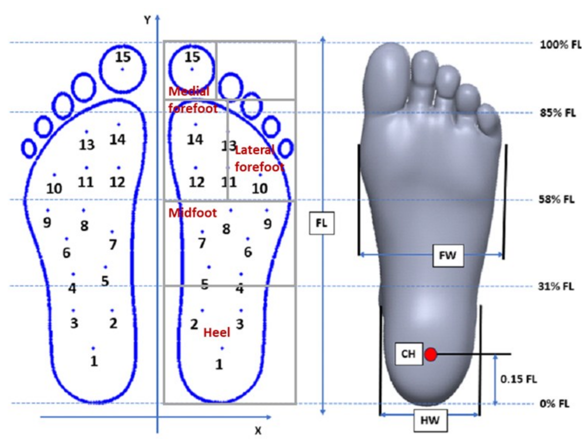
*2.2. Instruments and Measurements*

The plantar pressure measurement apparatus incorporates Force Sensing Resistor (FSR) type 402 sensors, which are integrated into the foot sensor mat. A total of fifteen sensors are judiciously allocated across both the left and right soles to encompass critical anatomical regions, including the heel, midfoot, forefoot, and toes. This system is designed to acquire real-time pressure data, which is crucial for comprehensive biomechanical evaluation. Figure 1(a) illustrates a block diagram of the system, wherein the FSR sensor relays an analog signal to the Arduino Mega 2560 microcontroller, which subsequently transforms it into a digital signal and conveys it to the computer through a Python-based interface. Data visualization is manifested as a pressure map or a real-time graph, offering an intricate representation of load distribution across the foot. Figure 1(b) depicts the sensor configuration on the plantar surface, accompanied by a horizontal reference line that demarcates the foot into pressure zones based on the percentage of foot length.




(a)

| Foot | Sensor | X | Y | Z |
|---|---|---|---|---|
| Left | 1 | -50 | 38 | 0.0 |
| | 2 | -35 | 65 | 0.0 |
| | 3 | -65 | 65 | 0.0 |
| | 4 | -65 | 90 | 0.0 |
| | 5 | -40 | 95 | 0.0 |
| | 6 | -70 | 115 | 0.0 |
| | 7 | -35 | 120 | 0.0 |
| | 8 | -57 | 135 | 0.0 |
| | 9 | -85 | 135 | 0.0 |
| | 10 | -80 | 160 | 0.0 |
| | 11 | -55 | 165 | 0.0 |
| | 12 | -30 | 165 | 0.0 |
| | 13 | -55 | 190 | 0.0 |
| | 14 | -30 | 195 | 0.0 |
| | 15 | -27 | 234 | 0.0 |
| Right | 1 | 50 | 38 | 0.0 |
| | 2 | 35 | 65 | 0.0 |
| | 3 | 65 | 65 | 0.0 |
| | 4 | 65 | 90 | 0.0 |
| | 5 | 40 | 95 | 0.0 |
| | 6 | 70 | 115 | 0.0 |
| | 7 | 35 | 120 | 0.0 |
| | 8 | 57 | 135 | 0.0 |
| | 9 | 85 | 135 | 0.0 |
| | 10 | 80 | 160 | 0.0 |
| | 11 | 55 | 165 | 0.0 |
| | 12 | 30 | 165 | 0.0 |
| | 13 | 55 | 190 | 0.0 |
| | 14 | 30 | 195 | 0.0 |
| | 15 | 27 | 234 | 0.0 |

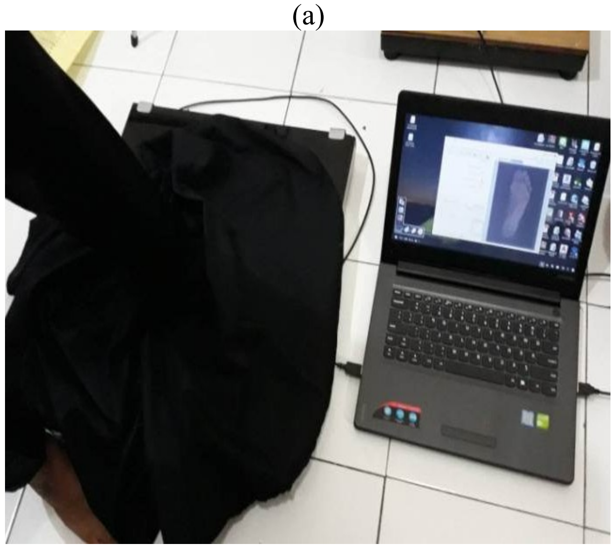



(b)

**Figure 1.** (a) Schematic representation of the static load measurement system (b) positioning of the sensors within the soles.

Foot assessments were conducted utilizing the Foot Mat Sensor (FMS) and the Foot Digital Scanner (FDS) integrated within the complete apparatus, as demonstrated in Figure 2. The FMS measured force distribution on the sole during static conditions, whereas the FDS produced a three-dimensional digital representation of foot morphology, documenting essential parameters such as length, width, and heel circumference. This three-dimensional visualization was further enhanced by sensor coordinates (X, Y, Z) and was employed to compute the Foot Contact Area (FCA), a pivotal metric in categorizing arch types. Such information bears significant relevance for clinical applications, ranging from the diagnosis of foot disorders to the engineering of insoles and orthopedic footwear. This cohesive system enables precise and effective monitoring of plantar pressure distribution and is extensively applied within the realms of medical rehabilitation and the development of biomechanical devices.

(a)



(b)

**Figure 2.** Instrumentation for measurement (a) foot mat sensor (FMS) (b) digital foot scanner (FDS).

*2.3. Data Collection Procedure*

Table 1 delineates the physical metrics acquired through the measurement of participants' weight and height, which were subsequently employed to compute the Body Mass Index (BMI) utilizing the conventional formula [21]. The subsequent phase entailed a digital scanning procedure, wherein participants were required to stand barefoot on a sensor-integrated foot mat for a duration of 10 seconds. This apparatus autonomously captures the distribution of plantar pressure, encompassing measurements at the heel, mid-arch, and forefoot regions. The data derived from the scanning apparatus were utilized to ascertain the Foot Contact Area (FAC) and to categorize the sole type predicated on the Arch Index. According to the established methodology, foot soles are categorized into three principal classifications: High Arch (HA), Normal Arch (NA), and Low Arch (LA) [22].

**Table 1.** Participant characteristics include Body Mass Index (BMI), foot arch morphology, plantar pressure distribution, foot contact surface area, and associated risk levels.

| ID | BMI | Foot Arch Category | Heel Pressure (kPa) | Midfoot Pressure (kPa) | Forefoot Pressure (kPa) | FAC ($mm^2$) | Estimated Pressure (kPa) | Risk |
|---|---|---|---|---|---|---|---|---|
| 1 | 22,4 | NA | 220 | 100 | 200 | 999,89 | 10 | Low |
| 2 | 27,1 | NA | 280 | 150 | 310 | 11041,52 | 15 | Low |
| 3 | 16,1 | HA | 270 | 90 | 180 | 12072,32 | 8 | Low |
| 4 | 25,1 | LA | 400 | 200 | 330 | 12713,26 | 25 | High |
| 5 | 28,7 | NA | 370 | 250 | 320 | 12175,84 | 20 | High |
| 6 | 21,5 | NA | 270 | 130 | 210 | 10782,43 | 14 | Low |
| 7 | 19,2 | NA | 230 | 110 | 190 | 10987,26 | 10 | Low |
| 8 | 29,3 | LA | 370 | 240 | 350 | 12678,45 | 25 | High |
| 9 | 20,1 | HA | 280 | 120 | 220 | 10765,32 | 12 | Low |
| 10 | 21,5 | HA | 290 | 90 | 230 | 10978,91 | 9 | Low |

Note: High Arch (HA), Normal Arch (NA), and Low Arch (LA)

*2.4. Data Analysis*

The data analysis was executed using descriptive statistical methods to encapsulate essential parameters, including the mean, standard deviation, and distribution of plantar pressure measurements [23]. Linear regression analysis was employed to assess the correlation between BMI, foot type, and plantar pressure in the context of biomechanical risk. The biomechanical risk was subsequently stratified into three distinct levels: (1) low risk, characterized by the absence of excessive plantar pressure; (2) moderate risk, delineated by the presence of moderate plantar pressure in specific regions; and (3) high risk, indicated by augmented plantar pressure in the heel, mid-arch, or forefoot regions [24].

*2.5. Predictive Model Development*

A predictive model for biomechanical risk was formulated utilizing the Random Forest machine learning algorithm, which is lauded for its proficiency in analyzing complex nonlinear datasets [25]. The process commences with data preprocessing, which encompasses the normalization of plantar pressure values and FCA measurements to ensure uniformity in the data. The dataset was subsequently partitioned into two segments: 70% designated as the training set for model training and 30% allocated as the validation set for assessing predictive efficacy [26]. Model evaluation was executed utilizing metrics of accuracy, precision, and recall, which collectively furnish a holistic evaluation of the model's capacity to predict biomechanical risk with precision.

## 3. Results and Discussion

The findings of the study reveal a significant correlation between BMI, foot type, and the distribution of plantar pressure concerning biomechanical risk, as depicted in Figure 3. Participants exhibiting a high BMI (>25 kg/m²) were observed to display increased plantar pressure, particularly in the heel and forefoot regions. Moreover, individuals with Low Arch (LA) foot types exhibited irregular plantar pressure distribution, with the most pronounced pressure recorded in the midfoot region [27]. The average plantar pressure values derived from the data are as follows: heel pressure reached 350 kPa in individuals with a

BMI >25, in contrast to 250 kPa in those possessing a normal BMI; midfoot pressure was documented at 280 kPa in subjects with a Low Arch foot type, compared to 150 kPa in those with a Normal Arch; and forefoot pressure was registered at 300 kPa in subjects with a high BMI. These findings accentuate the critical necessity of comprehending the interrelationships among biomechanical factors for the effective management of risk within specific demographic groups [28].

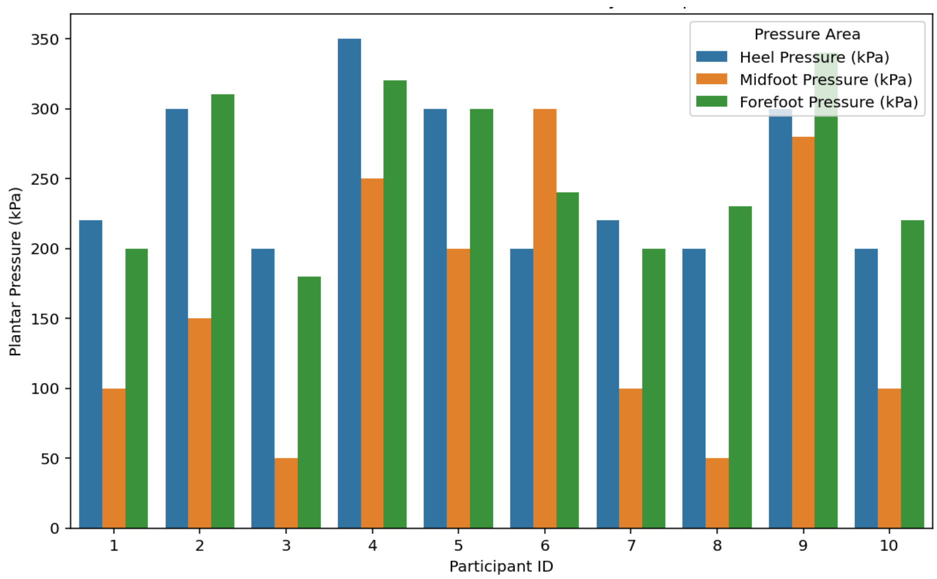



**Figure 3.** Distribution of plantar pressure across three distinct regions of the foot.

Based on the empirical data obtained from ten subjects (refer to Figure 3), Table 2 delineates that the mean pressure exerted in the heel region was quantified at 284.0 kPa, accompanied by a standard deviation of 25.12 kPa, thereby indicating that this particular area functions as the principal support locus during bipedal stance. The mean pressure observed in the mid-arch was 129.0 kPa, with a standard deviation of 21.66 kPa, while the average forefoot pressure was determined to be 214.5 kPa, with a standard deviation of 22.81 kPa. These outcomes are indicative of a conventional load distribution schema in static standing scenarios, wherein the heel and forefoot sustain greater loads in comparison to the mid-arch. Additionally, the foot contact area (FCA) revealed significant variances. Subjects exhibiting a Low Arch foot morphology demonstrated an average FCA of 12,500 mm², surpassing that of the Normal Arch category, which recorded an FCA of 10,500 mm². An augmented FCA is suggestive of an irregular plantar pressure distribution.

**Table 2.** Distribution of plantar load: mean values and standard deviations

| **Foot Area** | **Mean Pressure (kPa)** | **Standard Deviation (kPa)** |
|---|---|---|
| Heel | 284.0 | 25.12 |
| Midfoot | 129.0 | 21.66 |
| Forefoot | 214.5 | 22.81 |

*3.1. Inter-Subject Pressure Comparison*

To elucidate the variability of plantar pressure among individuals, a comparative analysis of heel pressure metrics was performed utilizing data from five specifically chosen participants. These participants were meticulously selected to embody a spectrum of Body Mass Index (BMI) classifications and diverse foot arch phenotypes. As illustrated in Table 3, heel pressure values exhibited considerable variation, with the minimum recorded at 220 kPa for a participant possessing a Normal Arch and a BMI of 22.4, and the maximum at 400 kPa for a participant characterized by a High Arch and a BMI of 25.1.

**Table 3.** Comparative Analysis of Heel Pressure Among Designated Participants

| Participant ID | BMI | Arch Type | Heel Pressure (kPa) |
|---|---|---|---|
| 1 | 22.4 | Normal Arch | 220 |
| 3 | 16.1 | High Arch | 270 |
| 4 | 25.1 | High Arch | 400 |
| 5 | 28.7 | Low Arch | 370 |
| 8 | 29.3 | Low Arch | 370 |

Notably, participants classified as Low Arch (IDs 5 and 8) and possessing elevated BMI values (28.7 and 29.3, respectively) demonstrated significantly heightened heel pressures, each attaining 370 kPa. This trend intimates a robust correlation between increased body mass, flat foot morphology, and augmented plantar loading in the heel region. Conversely, individuals exhibiting lower BMI and a High Arch (e.g., ID 3) displayed moderate heel pressure despite their structural predisposition. These findings bolster the hypothesis that both biomechanical foot architecture and body composition substantially affect plantar pressure distribution, particularly in regions of high loading such as the heel. Such insights are pivotal for identifying individuals at augmented risk for plantar stress-related pathologies and for guiding the formulation of more tailored intervention strategies.

*3.2. Correlations BMI and Biomechanical Risk*

Figure 4 elucidates that subjects with a BMI exceeding 25 (IDs 4, 5, and 9) tend to display a heightened biomechanical risk in comparison to their counterparts. Specifically, IDs 4 and 9 are classified as possessing high biomechanical risk, likely influenced by irregular plantar pressure distribution and an expanded foot contact area (FCA) [29]. Conversely, ID 5 is categorized as having moderate biomechanical risk, characterized by intermediate plantar pressure levels but exhibiting increased pressure asymmetry. In contrast, subjects with a BMI of less than 25, such as IDs 1, 2, and 7, generally manifest lower biomechanical risk due to a more uniform distribution of plantar pressure. These findings underscore the impact of BMI on patterns of plantar pressure distribution and related levels of biomechanical risk [30].

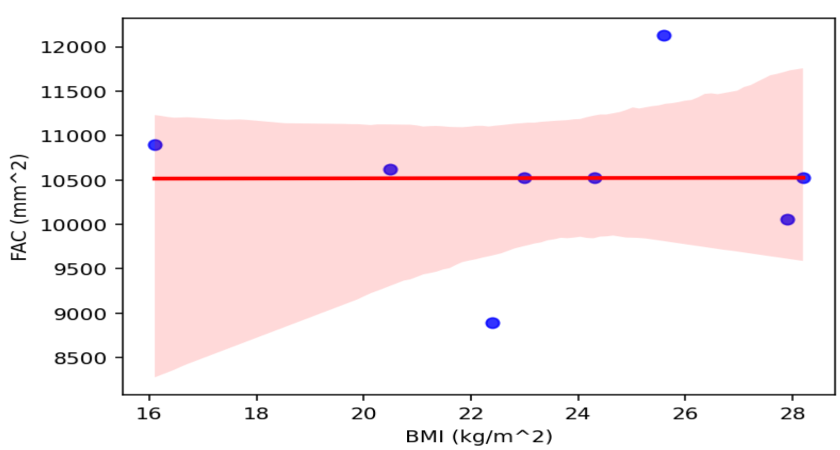
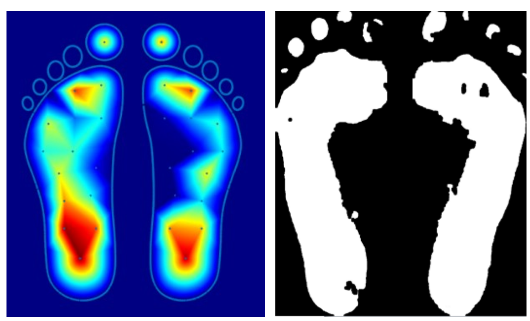



**Figure 4.** Correlation between BMI and FAC

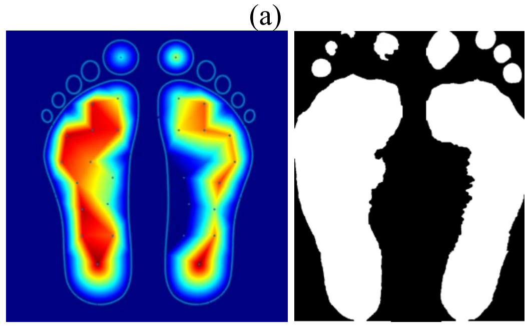
*3.3. Plantar Pressure and Sole Category*

Individuals exhibiting Low Arch (LA) foot morphology, as depicted in Figure 5 (IDs 4 and 8), demonstrate unique characteristics regarding plantar pressure distribution. Notably, the plantar pressure in the midfoot area has been observed to surpass that recorded in both the heel and forefoot regions [31]. This phenomenon indicates a deficiency in the foot arch's ability to facilitate equitable pressure distribution, leading to a heightened concentration of pressure within the midfoot zone. Furthermore, the foot contact area (FCA) associated with the Low Arch phenotype is greater than that observed in alternative foot types, as evidenced by ID 9, who recorded an FCA of 12,718.8 mm². These observations imply a correlation between foot arch morphology and the distribution of plantar pressure, which may elevate biomechanical risks for individuals with the LA foot type [27].

Conversely, the High Arch (HA) foot type is defined by a plantar pressure distribution that is predominantly localized to the heel and forefoot regions, with markedly reduced pressure detected in the midfoot area [32]. This condition is exemplified in Figure 6 for subjects ID 3, 9, and 10, where the uneven distribution of pressure signifies heightened localized stress in the heel and forefoot areas. Consequently, the FCA associated with the High Arch type is comparatively smaller than that of other foot arch configurations. For instance, subject ID 8 displayed an FCA of 10,508.24 mm², suggesting an inadequate distribution of pressure by the foot arch. This pressure discrepancy is frequently linked to various biomechanical hazards, including heightened stress on the metatarsal bones and heel, which may culminate in discomfort or injury if not adequately addressed. In contrast, the Normal Arch (NA) foot type illustrates a more equitable distribution of plantar pressure across all segments of the foot, encompassing the heel, mid-arch, and forefoot. Subjects possessing the NA foot type, as represented in Figure 7 (IDs 1, 2, 5, 6, and 7), display a balanced plantar pressure profile, thereby affording optimal stability throughout daily activities. The FCA for the NA foot type occupies a moderate range, averaging approximately 11,000 mm². This measurement reflects the foot arch's capability to effectively distribute pressure, thereby mitigating the risk of biomechanical injury and promoting proper postural alignment. The synthesis of uniform pressure distribution and an optimal FCA positions the NA foot type as the most advantageous foot arch configuration for the facilitation of human biomechanical functions [33].



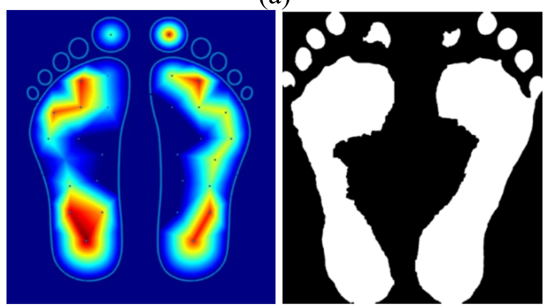
(a)



(b)

**Figure 5.** Visualization of FMS and FDS data collection outcomes (a) ID 4 (b) ID 8.

(a)



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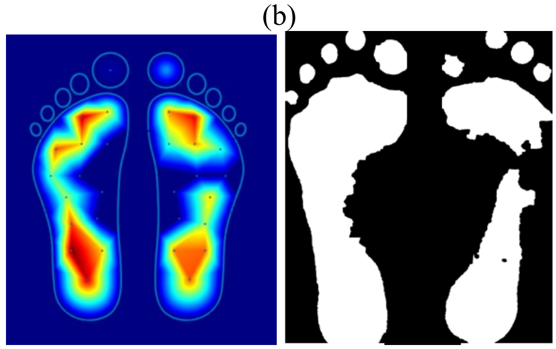
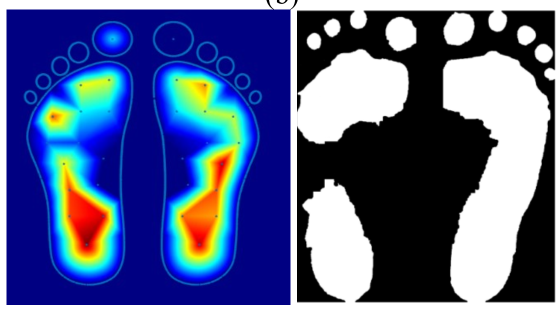


(c)

**Figure 6.** Visualization of FMS and FDS data collection outcomes (a) ID 3 (b) ID 9 (b) ID 10

(a)

(b)



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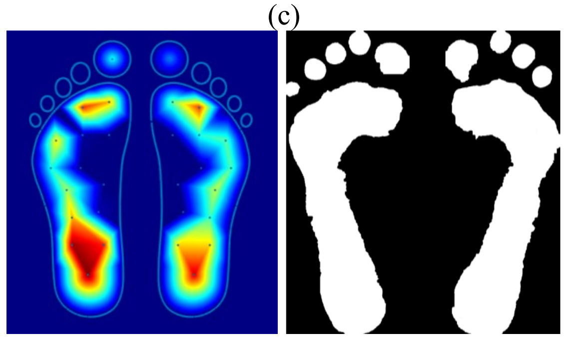
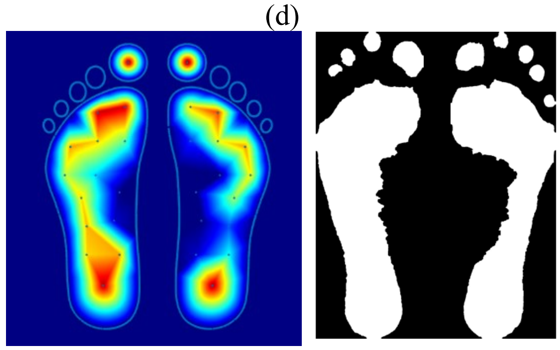


(d)



(e)

**Figure 7.** Visualization of FMS and FDS data collection outcomes
(a) ID 1 (b) ID 2 (c) ID 5 (d) ID 6 (e) ID 7.

*3.4. Pressure Asymmetry*

Subjects exhibiting plantar pressure asymmetry of ≥ 20 kPa, as evidenced in subjects ID 6 and ID 9, exhibited an elevated biomechanical risk. This pronounced pressure asymmetry signifies an imbalanced distribution of load between the right and left lower extremities. Such an imbalance may augment localized pressure in particular regions, such as the heel or midfoot, potentially resulting in biomechanical injuries, which may include chronic pain, postural instability, and soft tissue trauma [34]. Conversely, subjects demonstrating pressure asymmetry levels below 10 kPa, as identified in IDs 1, 3, and 7, revealed a more equitable distribution of plantar pressure across the feet. This observation is indicative of enhanced biomechanical stability, characterized by the absence of undue stress concentration in any singular area. Such a state diminishes the likelihood of injury and fosters optimal biomechanical function, particularly during activities such as ambulation and running. Therefore, the degree of plantar pressure asymmetry may serve as a critical metric for evaluating biomechanical stability and injury susceptibility in individuals [35].

### *3.5. FCA (Foot Contact Area) Factor*

A substantial Foot Contact Area (FCA) of ≥ 12,500 mm², as documented in subjects IDs 6 and 9, signifies the presence of a flat foot arch type (Low Arch). This condition denotes that the foot arch is either low or nearly flat, thereby constraining the foot's capacity to distribute pressure uniformly. As a result, plantar pressure tends to accrue in specific regions, such as the midfoot, thereby heightening the risk of biomechanical injuries, which may include chronic pain and compromised stability [27]. In contrast, a reduced FCA (approximately 10,000 mm²), as documented in subjects IDs 3 and 8, correlates with a high arch type. In this scenario, plantar pressure is predominantly concentrated in the heel and forefoot regions, while the midfoot experiences minimal pressure. Although pressure distribution within the High Arch type is more localized, this condition still represents a biomechanical risk, particularly due to the potential for excessive localized stress in specific regions [32]. These risks encompass injuries such as heel pain and metatarsalgia, which arise from suboptimal weight distribution. Consequently, FCA can function as a significant indicator for identifying foot arch types and their concomitant biomechanical risks.

### *3.6. Pressure Distribution and Gradient Visualization in the Mid-Foot Area*

Figure 7 delineates the segmentation of the midfoot region into three principal sections: lateral (lat) arch, middle (mid) arch, and medial (med) arch, each assessed utilizing six sensors (4, 5, 6, 7, 8, and 9). This segmentation aims to capture the pressure distribution along the foot's arch. The lat arch pertains to the lateral aspect of the foot, the mid arch occupies the central domain, and the med arch is located on the medial aspect of the foot. This sensor arrangement is meticulously crafted to map pressure variations across diverse foot arch types, ranging from high arches to normal arches and flat feet. The results depicted in the figure provide an initial representation of foot contact with the surface according to arch type [36].

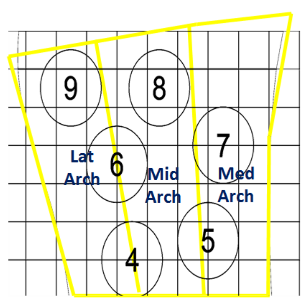
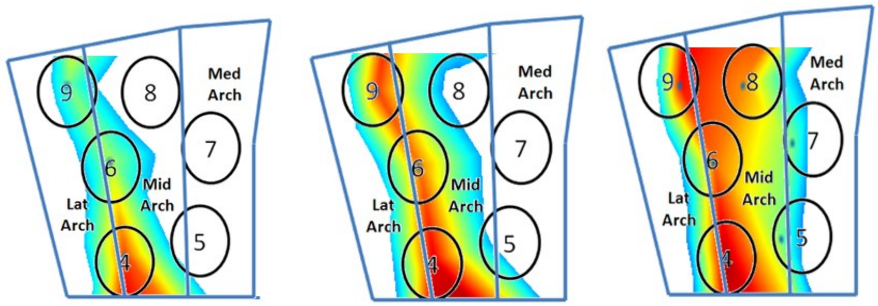



**Figure 7.** Graphical representation of the mid-foot region utilizing multiple sensors integrated within the FMS measurement apparatus.

Figure 8 delineates the distribution of plantar pressure through a color gradient representation for three distinct foot arch types. In this gradient, the color red signifies regions of elevated pressure, whereas blue represents areas of diminished pressure. In individuals characterized by a High Arch foot type, plantar pressure is primarily concentrated in the lateral and medial arch regions, while the mid arch displays negligible pressure. This distribution pattern implies a supinated foot posture, which is defined by a diminished contact interface between the midfoot area and the ground surface [27]. Conversely, the Normal Arch foot type reveals a more homogeneous pressure distribution, with discernible pressure variations across the regions, indicative of balanced biomechanical function. In subjects with flat feet, the midfoot region demonstrates uniformly elevated pressure, suggesting a propensity toward overpronation, which may precipitate excessive loading on the structural components of the foot.




(a) (b) (c)

**Figure 8.** Color gradient representation (arch) utilizing multiple sensors situated in the mid-foot region.

*3.7. Biomechanical Risks*

Subjects categorized as high risk typically present a confluence of elevated Body Mass Index (BMI) exceeding 25, marked plantar pressure asymmetry, and uneven pressure distribution throughout the foot. In contrast, individuals deemed low-risk generally maintain a normal BMI, exhibit a moderate foot contact area (FCA), and display relatively equilibrated plantar pressure across the heel, midfoot, and forefoot regions [37]. These observations align with prior research indicating that an elevated BMI is associated with increased plantar pressure, particularly within the heel and forefoot areas. The augmentation of body weight in individuals with a high BMI results in a redistribution of plantar pressure, consequently heightening the likelihood of injuries such as plantar fasciitis [38]. Additionally, the irregular pressure distribution noted in individuals with the Low Arch foot type is intimately linked to biomechanical instability.

Elevated plantar pressure in the midfoot region among individuals possessing the Low Arch foot type suggests that the flattened arch is ineffectively managing pressure distribution, thereby amplifying the risk for chronic pain and various biomechanical disorders. In contrast, individuals with the High Arch type exhibit a more concentrated plantar stress in the heel and forefoot, which may intensify the risk of injury due to localized stress in these anatomical regions [39].

Figure 9 introduces a predictive model constructed utilizing the Random Forest algorithm, which attained an accuracy rate of 85% in the classification of biomechanical risks. The assessment of the model through precision and recall metrics substantiated its efficacy in forecasting biomechanical risk based on BMI, foot morphology, and plantar pressure distribution [24].

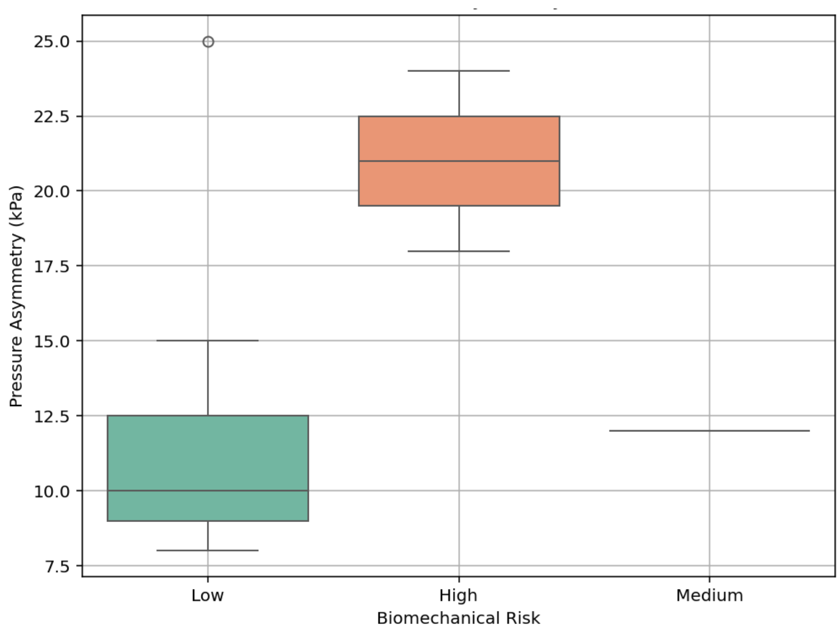



**Figure 9.** Distribution of pressure asymmetry correlated with risk assessment.

This study is subject to several limitations, including a relatively modest sample size (n=10), which constrains the generalizability of the findings and necessitates cautious interpretation. Subsequent investigations involving larger sample size and dynamic plantar pressure analyses, such as those occurring during ambulation or running, are strongly advocated to validate and expand upon these conclusions.

## 4. Conclusion

This investigation elucidates a noteworthy correlation between Body Mass Index (BMI), foot morphology, and the distribution of plantar pressure in assessing biomechanical vulnerability. Participants exhibiting a high BMI (>25 kg/m²) in conjunction with a Low Arch (LA) foot structure are identified as being at an increased biomechanical risk due to the irregular distribution of plantar pressure, particularly manifesting in the midfoot and forefoot regions. The predictive model for biomechanical risk, constructed employing the Random Forest algorithm, showcased a commendable accuracy rate of 85%, underscoring the promise of Digital Footprint Scanner technology in facilitating more individualized diagnostics and preventive measures for biomechanical injuries. Nonetheless, constraints such as a limited sample size and dependence on static evaluations pose significant obstacles that necessitate consideration in forthcoming research, which should encompass trials with a more extensive participant demographic and the assessment of plantar pressure under dynamic scenarios, such as ambulation or running. The results of this inquiry make a substantial contribution to the progression of biomechanical technology, particularly in the enhancement of diagnostic precision and the formulation of more efficacious intervention methodologies.

## 5. Reference

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