Exploring Biomechanical and Clinical Factors in Diabetic Foot Ulcer Risk Assessment

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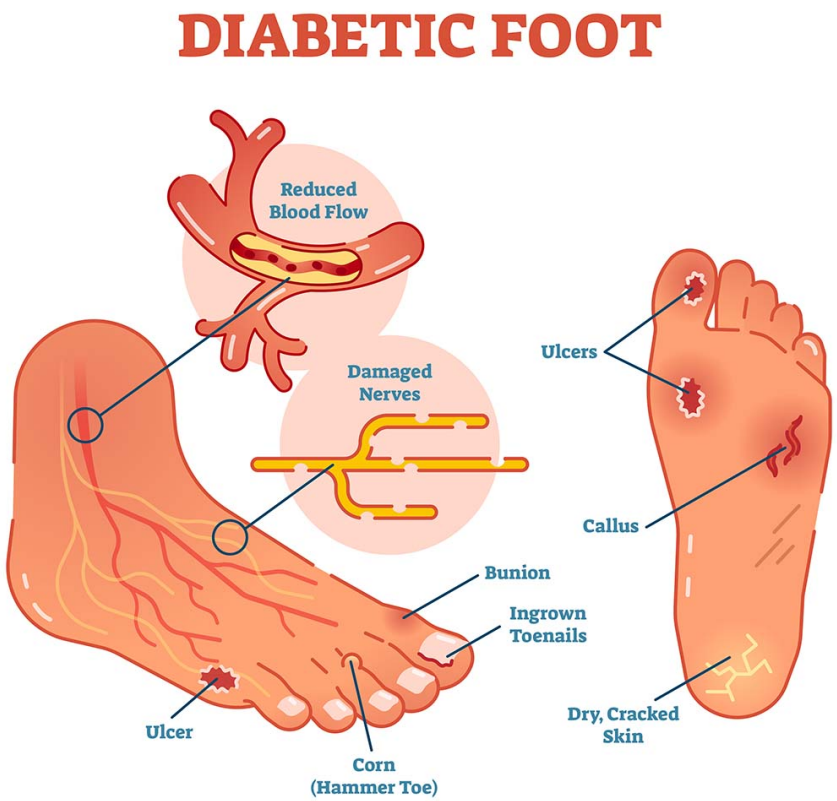
August 24, 2025

Outline

Introduction

- **Diabetes:** A long-term disease where blood sugar stays high because the body makes too little insulin or does not use it well. It can harm nerves and blood vessels.
- **Neuropathy:** Nerve damage from diabetes that can cause foot pain, numbness, or weakness.

Diabetic Foot Ulcers



Risk Factors for Diabetic Foot Ulcers

- **Neuropathy:** Less feeling in the feet, so injuries happen more easily.
- **Poor Circulation:** Blood flow is weak, so wounds heal slowly.
- **Foot Deformities:** Feet have unusual shapes, causing more pressure on some spots.

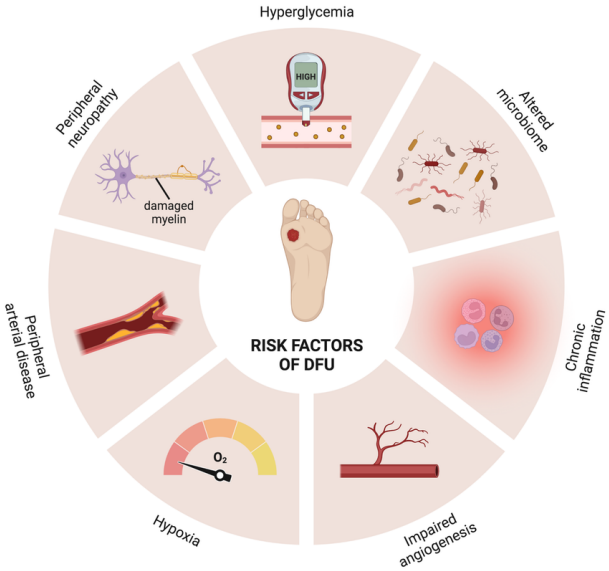


Figure: Plantar Pressure Map

Why Study Diabetic Foot Ulcers?

- Over 4 million adults in France are living with diabetes (2024).[1]
- Diabetic Foot Ulcers (DFUs) cause more than 10,000 amputations each year.
- **Goal:** Create a tool to study diabetic foot data and help doctors identify patients at risk before ulcers appear.

[1] World Health Organization, 2016; International Diabetes Federation, 2024

Objectives

- **Identify key risk markers** (e.g., tissue stiffness, plantar pressure).
- **Explore left–right foot differences** as warning signs.
- **Apply unsupervised learning** (e.g., clustering)
- **Compare clusters with IWGDF grades** [2]

[2] IWGDF (International Working Group on the Diabetic Foot)

Data Collection

- Study done in a day-hospital with ethical approval.
- Participants signed consent forms.
- Included adults 18–65 with diabetes.
- Excluded pregnant, breastfeeding, or legally protected people.

The DIAFOOT Dataset

- **Participants**: 21 diabetic patients (11 F, 10 M).
- **Age**: Mean 56.8 years.
- **BMI**: Mean 25.83 kg/m^2

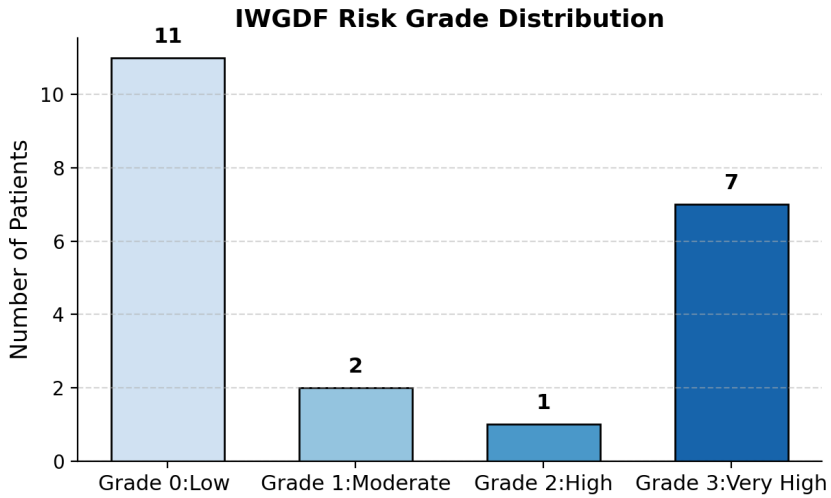
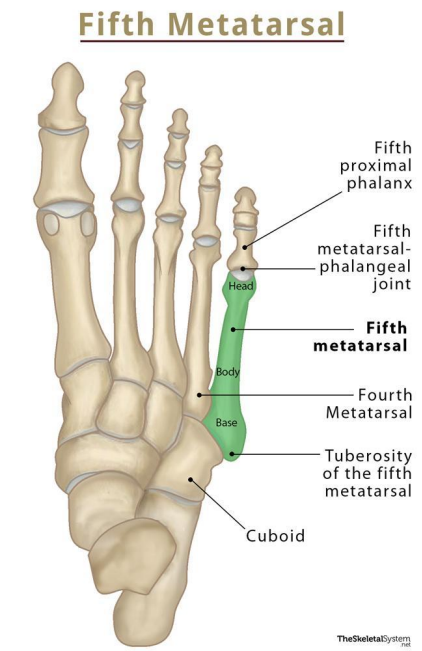


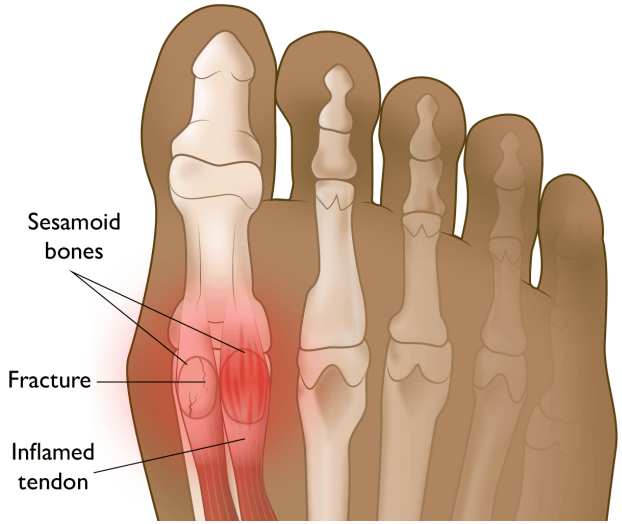
Figure: IWGDF Grades

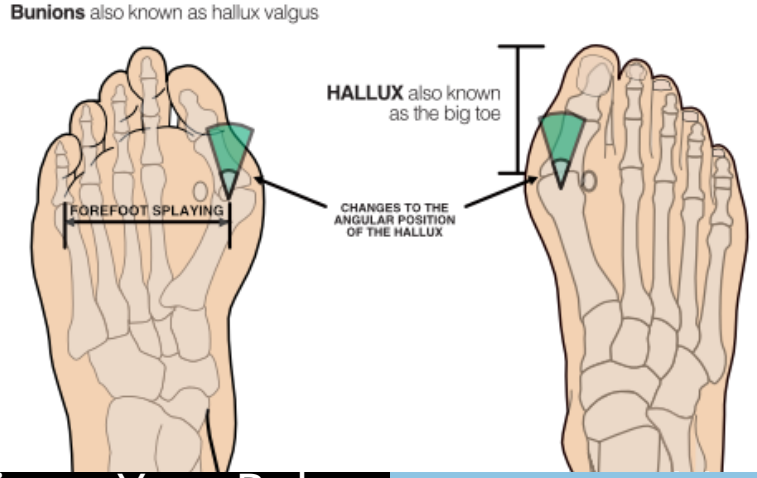
Data Parameters

- **Anthropometric:** BMI, height, weight
- **Vascular:** Ankle and big toe blood pressure
- **Neurological:** Michigan score, SUDOSCAN (hands/feet)
- **Biomechanical:** Foot pressure (SESA, hallux, TM5), tissue stiffness
- **Imaging:** Ultrasound tissue thickness
- **Thermal:** Foot temperature and normalized values

Three zones Example







Analysis Pipeline

Streamlit Dashboard

- **Platform**: Built using Streamlit, A dynamic, Python-driven platform for real-time data exploration and visualization.
- **Data Source**: Excel file with 'DIAFOOT' sheet containing patient metrics.
- **Key Features**: Descriptive statistics, normality tests, clustering,correlations and comparative analyses.
- **Tools**: Pandas (data handling), NumPy (numerical), Scikit-learn (ML,, clustering), Matplotlib, Seaborn (visuals), `scipy.stats` (hypothesis testing), Statsmodels (MANOVA, regression),

Review of Statistics: p-value

- **p-value:** Shows if a result is real or by chance.
- Small p-value $< 0.05 \rightarrow$ **significant** (result likely real)
- Large p-value $>= 0.05 \rightarrow$ **not significant** (result may be by chance)
- Used to decide whether to reject the null hypothesis.

Explore the DIAFOOT Analysis Dashboard

https://diafoot-analysis.streamlit.app/

Upload data, analyze it, and see important results easily.

Try it now!

Asymmetry Insights

Significant Left-Right Differences

- **TM5(fifth metatarsal) Pressure**: Right (36.93 kPa) $>$ Left (26.34 kPa), p = 0.0054.
- **Hallux Stiffness**: Right higher, p = 0.0498.
- **Temperature (Plantar Arch, Lateral Sole)**: Right warmer, p $<$ 0.01.

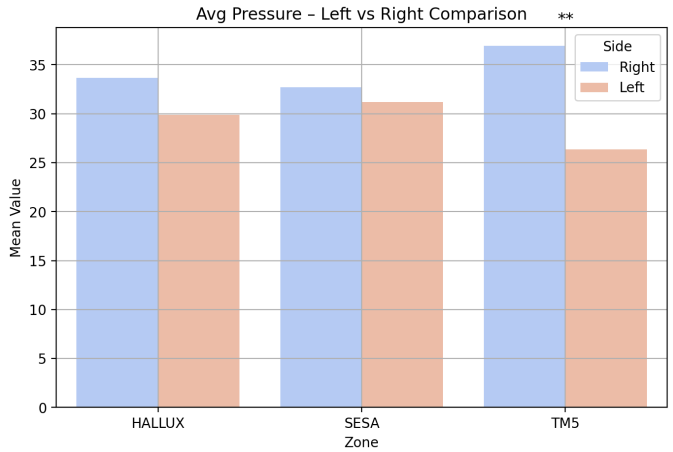


Figure: Pressure Asymmetry

Group Differences: Low vs. High Risk

Parameter	Grades 0-1	Grades 2-3	p-value
Michigan Score	11.69	4.13	0.00053
Tissue Thickness SESA R (mm)	9.55	4.17	0.0099
Heel Temperature R (°C)	25.85	28.55	0.0188

Table: Significant Group Differences

- Higher-risk patients have lower Michigan scores, thinner tissue, and warmer heels, showing higher ulcer risk.

Clustering Analysis

- Clustering done with and without IWGDF grades
- **PCA:** 2D visualization of patient data.
- **Clustering:** Agglomerative, KMeans, GMM; 2–6 clusters.
- **Metrics:** Silhouette, Calinski–Harabasz, Davies–Bouldin, ARI, NMI.
- **Feature importance:** LASSO, Random Forest, ANOVA.
- **Group differences:** MANOVA, p-values indicate significance.

Clustering Metrics

Algorithm	Silhouette	CH Score	DB Score	ARI	NMI
With IWGDF Grade					
Agglomerative (Ward)	0.553	43.959	0.485	0.794	0.778
Agglomerative (Average)	0.553	43.959	0.485	0.794	0.778
KMeans	0.553	43.959	0.485	0.794	0.778
Gaussian Mixture Model	0.344	33.367	0.939	0.490	0.654
Without IWGDF Grade					
Agglomerative (Ward)	0.539	40.721	0.532	0.794	0.778
Agglomerative (Average)	0.539	40.721	0.532	0.794	0.778
KMeans	0.539	40.721	0.532	0.794	0.778
Gaussian Mixture Model	0.345	31.163	0.957	0.490	0.654

Clustering Results

Key Insights

- Focused parameters (e.g., Michigan Score, tissue thickness) yield better clusters (Silhouette 0.55) than full set (0.22), likely due to noise from less-informative features.
- Top predictors: Michigan Score, tissue thickness (HALLUX, TM5), temperature.
- IWGDF grades improve clustering but miss some variability.

Feature Importance

- **Logistic Regression (LASSO):** Michigan Score, Michigan Score 2, Tissue Thickness (SESA_R).
- **Random Forest:** Tissue Thickness (TM5_L, SESA_R), Michigan Score.
- **ANOVA (Eta^2):** Tissue Thickness (HALLUX_R), Michigan Score.

Clustering Rankings:

- **With IWGDF Grade:** Michigan Score + IWGDF grade, then Tissue Thickness (TM5_L, SESA_R).
- **Without IWGDF Grade:** Michigan Score + Tissue Thickness (SESA_R, HALLUX_R, TM5_L).

Correlations

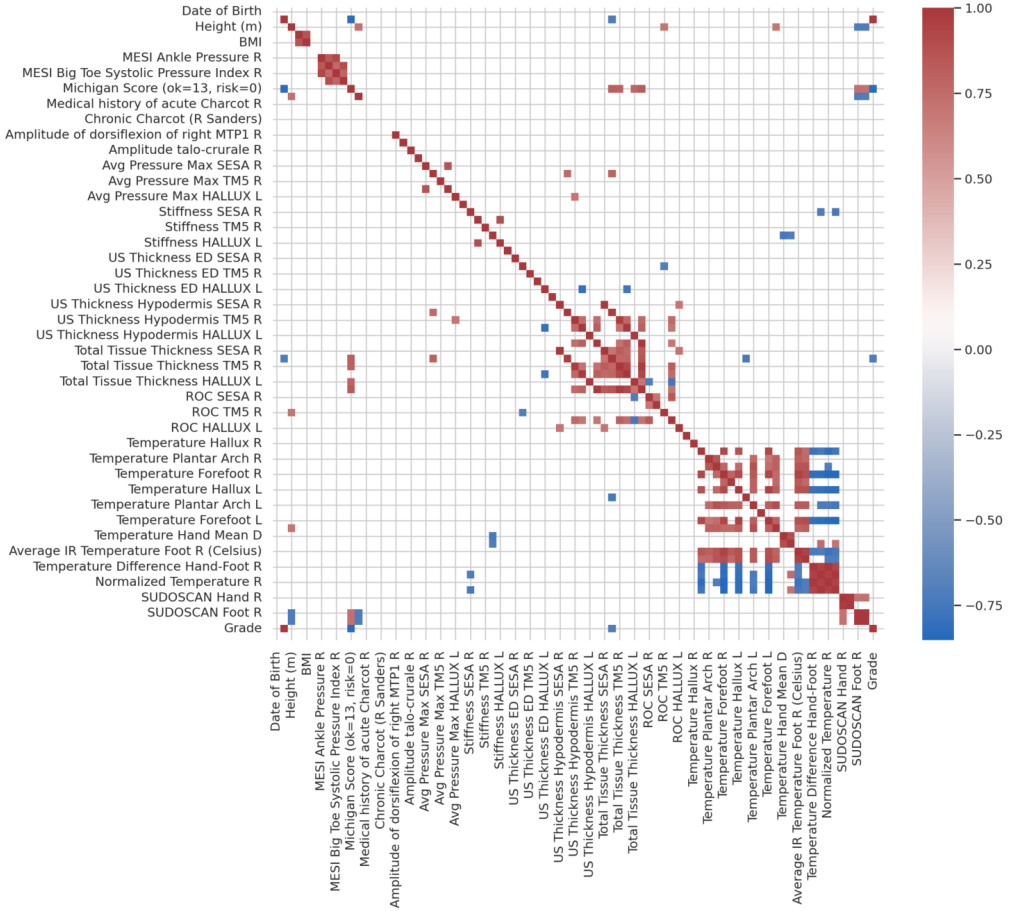


Figure: Correlogram ($|r| > 0.7$)

To summarize

- **Left–right asymmetries** are important early signals.
- **Clustering** using selected features reveals meaningful patient groups.
- **Important indicators** include Michigan Score, tissue thickness, and temperature.
- **Take-home message**: Combining clinical and biomechanical data improves risk screening.

Limitations and Future Directions

Challenges

- Small sample (21 patients) limits statistics.
- Uneven patient numbers in IWGDF grades.
- Some measurements (ultrasound, pressure) may be biased.

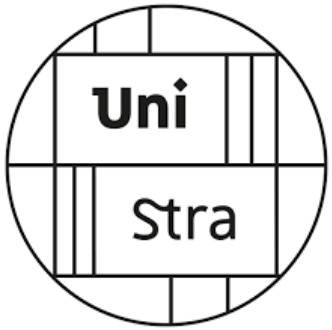
Next Steps

- Include more patients for stronger results.
- Use better ways to handle missing data and track patients over time.
- Try deep learning to improve prediction.

Personal Reflections

Internship Experience

- Improved Python and data analysis skills.
- Collaborated with supervisors to ensure medical accuracy.
- Learned to apply data science in healthcare.



Useful URLs

- Streamlit Cloud
- Scikit-learn Clustering Documentation

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Thank You!

Questions?

Thank you for your attention!