



# Impact of Poor Glycemic Control and Vascular Complications on Diabetic Foot Ulcer Recurrence

Alva C. Mustamu<sup>1\*</sup>, Elisabeth Samaran<sup>1</sup>, Difran Nobel Bistara<sup>1</sup>

## Abstract

**Background:** Diabetes mellitus is a growing global health issue that leads to serious complications like diabetic foot ulcers (DFUs), which can worsen health and increase death rates in diabetic patients. In Sorong, Southwest Papua, Indonesia, the recurrence of DFUs is a major public health problem, affecting patients' well-being and adding significant healthcare costs. This study aimed to identify the factors that contribute to DFU recurrence in this region to help improve prevention and treatment strategies. **Methods:** A cross-sectional study was conducted in Sorong, Indonesia, including 53 diabetic patients with recurrent DFUs. Data were collected through structured interviews, physical examinations, and laboratory tests. Risk factors such as metabolic, vascular, behavioral, and demographic elements were analyzed. Statistical analysis, including univariate, bivariate, and multivariate techniques, was performed to identify independent predictors of DFU recurrence. **Results:** The study found that poor glycemic control, with a mean HbA1c of  $8.3 \pm 1.4$ , and vascular complications, such as peripheral artery disease and neuropathy, were the most significant predictors of DFU recurrence. Behavioral factors like smoking and physical inactivity, along with longer diabetes duration and previous

ulcer history, also showed a strong correlation with recurrence. Logistic regression identified HbA1c levels, peripheral artery disease, and smoking habits as independent predictors. **Conclusion:** This study determined the need for comprehensive care that focuses on controlling blood sugar levels, managing vascular issues, and promoting healthy behaviors to prevent diabetic foot ulcer recurrence in Sorong, Southwest Papua. Future efforts should target these risk factors to lower recurrence rates and improve patient health. More research is needed to find effective ways to prevent DFU recurrence in this population.

**Keywords:** Diabetic foot ulcer, Recurrence, Glycemic control, Vascular complications, Health behaviors

## Introduction

Diabetes mellitus is an increasingly prevalent condition worldwide, posing significant challenges to public health and establishing itself as a critical public health issue (Choudhury & Devi Rajeswari, 2021; Hossain et al., 2024; Lancet, 2023; Ong et al., 2023; Ruze et al., 2023; Tomic et al., 2022; Xie et al., 2022; Yu et al., 2024). Foot ulcer development is among the most concerning complications associated with this condition. Diabetic foot ulcers (DFU) remain a leading cause of morbidity and mortality in the diabetic population (Andrikopoulou et al., 2024; Baig et al., 2022; Bundó et al., 2023; Chen et al., 2023; Deng et al., 2022; Gallagher et al., 2024; Ibrahim et al., 2024; Jalilian et al., 2020; Jeyaraman et al., 2019; Mashili et al., 2019; Popa et al., 2023; Rastogi et al., 2020; Rubio et al., 2020; Tola et al., 2021; Waibel et al., 2024). The increasing incidence and prevalence of DFU, both nationally and globally,

**Significance** | This study identifies key risk factors of glycemic control, vascular issues, and behaviors driving diabetic foot ulcer recurrence in Sorong

\*Correspondence. Alva C. Mustamu, Nursing Department, Politeknik Kesehatan Kemenkes Sorong, Sorong, Indonesia.  
E-mail: alvamustamu@gmail.com

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## Author Affiliation.

<sup>1</sup> Nursing Department, Politeknik Kesehatan Kemenkes Sorong, Sorong, Indonesia.

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underscore the urgent need to address this issue (Ababneh et al., 2022; Alharbi & Sulaiman, 2022; Andrikopoulou et al., 2024; Baig et al., 2022; Bezerra et al., 2023; Bonnet & Sultan, 2022; Brousseau-Foley & Blanchette, 2020; Gallagher et al., 2024; Jeffcoate et al., 2024; Kropp et al., 2023; Lo et al., 2023; Silva-Tinoco et al., 2024; Søndergaard et al., 2023; Tan et al., 2024; Tuglo et al., 2021; Waibel et al., 2024; Z. Wang et al., 2024)

In Sorong, Southwest Papua, Indonesia, there is an observed increase in the incidence of Diabetic Foot Ulcer (DFU) cases (Mustamu, 2024). The global prevalence of DFU among individuals with diabetes is estimated to range from 15% to 25% (Al-Rubeaan et al., 2015). According to the 2023 Indonesian Health Survey (SKI), the prevalence of diabetes is projected to continue rising, with an estimated rate of 10.7% in 2023. The distribution of physician-diagnosed diabetes types in Southwest Papua indicates that type 1 diabetes constituted 25.5%, type 2 diabetes comprised 25.3%, gestational diabetes accounted for 3.4%, and 45.7% of the population were unaware of their specific diabetes classification (BKPK, 2023). Furthermore, only 31.1% of the non-diabetic population aged  $\geq 15$  years have reported checking their blood glucose levels, while 68.9% have never done so (SKI, 2023). This statistic indicates a deficiency in routine health screening, particularly for early diabetes detection, which contributes to an increase in complications, such as DFU. In Sorong, the rising incidence of DFU cases is a significant concern due to limited healthcare infrastructure and a lack of specialized diabetes care services (Mustamu et al., 2020). This underscores the necessity for more cost-effective and targeted healthcare interventions in underserved areas, such as Sorong. The consequences of recurring DFU are severe, resulting in diminished quality of life and substantial healthcare expenditures for individuals, families, and healthcare systems (Abdalla et al., 2023; Afonso et al., 2021; Costa et al., 2022; Guan et al., 2024; Hashempour et al., 2024; Ruiz-Muñoz et al., 2024; Swaminathan et al., 2024; Zamani et al., 2021).

Consequently, it is imperative to elucidate the factors contributing to DFU recurrence to facilitate improved interventions that can enhance patient outcomes and reduce healthcare costs. A comprehensive understanding of the factors contributing to DFU recurrence is imperative for its management and prevention. While previous research has endeavoured to elucidate the causative factors, they remain complex and multidimensional, including the intrinsic nature of DFU itself. Metabolic, vascular, disease duration, behavioural, morphological, treatment, demographic, and physical factors all contribute to the risk of DFU recurrence (Baig et al., 2022; Banik et al., 2020; El Hage et al., 2022; Guo et al., 2022, 2023; Haryanto et al., 2024; Hicks et al., 2020; Huang et al., 2019; Lee et al., 2024; Ogurtsova et al., 2021; Piran et al., 2024; Stegge et al., 2021;

Y. Wang et al., 2022; Xu et al., 2024; Yazdanpanah et al., 2024; Yunir et al., 2021).

However, the extant literature, particularly concerning populations from Sorong, Southwest Papua, Indonesia, remains insufficient due to the limited number of studies examining the factors associated with DFU recurrence. The literature on the topic of the failed

diabetic foot ulcer exhibits several limitations. Previous studies on diabetic foot ulcers in Indonesia have primarily focused on urban populations in Java and Sumatra, with limited research exploring the eastern regions, including Papua. Mustamu et al. (2020) conducted a study highlighting the growing number of DFU cases in Sorong, yet comprehensive data on the factors contributing to recurrence are lacking. Similarly, research by (Yunir et al., 2021) emphasized the need for region-specific strategies in managing diabetic complications, particularly in underserved areas such as Papua. Consequently, more comprehensive and detailed research is necessary to address this knowledge gap and enhance our understanding of DFU prevention and recurrence in this region.

This study aimed to identify the key factors contributing to diabetic foot ulcer recurrence in Sorong, Southwest Papua, Indonesia. To accomplish this objective, we conducted a comprehensive analysis of risk factors, including metabolic, vascular, disease duration, behavioural, morphological, treatment, demographic, and physical factors, associated with DFU recurrence in this region. Furthermore, the research seeks to enhance the understanding of DFU recurrence risk factors, specifically within the Sorong area, Southwest Papua, Indonesia. This investigation was designed to expand the knowledge base regarding DFU recurrence, particularly in this geographically defined area. The Sorong region faces challenges in addressing diabetes and its associated complications due to a paucity of trained healthcare personnel and inadequate medical infrastructure. Sociocultural factors also exert a significant influence, with traditional beliefs and limited health literacy impacting patient adherence to diabetes treatment regimens (Rismayanti et al., 2022). Comprehending these local dynamics is crucial for implementing efficacious interventions tailored to the community's specific needs.

## 2. Methodology

### 2.1 Study Location and Design

This investigation was conducted in the Sorong Regency and City, Southwest Papua, Indonesia, due to the increasing incidence of diabetic foot ulcers (DFUs) in the region. The area was selected based on the high prevalence of diabetic patients with DFU recurrence, providing both geographical and population relevance to the investigated problem. A cross-sectional research design was employed to collect data at a single time point from the study population.

### 2.2 Sample Size, Inclusion Criteria, and Sampling Method

The estimated sample size for this study was determined to be 53 diabetic patients with recurrent diabetic foot ulcers (DFUs) in Sorong Regency and City, Southwest Papua, Indonesia. The sample population was selected based on patients with DFUs and recurrence, residing in Sorong, who provided informed consent to participate in the study. Patients with other significant medical conditions that could potentially limit their participation in the study were excluded.

### 2.3 Data Collection and Measurement

Data sources for this investigation will be obtained from interviews, questionnaires, physical examinations, and diagnostic tests. The primary investigative method is a questionnaire encompassing inquiries regarding various demographic characteristics, medical

history, health-related behaviours, and wound care knowledge. This structured questionnaire will facilitate the assessment of patients' awareness levels concerning wound care practices and associated risk factors. Additionally, anthropometric measurements will be

conducted to evaluate anatomical morphology features, including foot deformities, plantar ulcers, and specific wound locations. Metabolic and vascular parameters to be assessed include HbA1c %, Cholesterol, LDL, HDL, serum creatinine, total bilirubin, and UACR. Further data to be extracted from patient records include duration of diabetes, length of hospital stay, previous amputation records, and history of cardio-cerebrovascular diseases. Smoking status, physical activity levels, dietary habits, and blood glucose monitoring practices will be evaluated through questionnaires. Supplementary information, such as age, gender, BMI, and white blood cell count of all participants, will also be recorded.

### 2.4 Ethical Considerations

Approval for this study was obtained from the Research Ethics Committee of the Health Polytechnic of the Ministry of Health in Sorong, Indonesia (Ref No: DM.03.01/4.1/178/2023). The research adhered to ethical principles concerning participants' rights, privacy, and informed consent. Each participant received an information sheet detailing the study's nature, objectives, procedures, potential benefits, and associated risks. Participation was entirely voluntary, with written informed consent obtained from all participants. Data collection was conducted confidentially, and no personal identifiers were utilized during data analysis. All identifiable information was encrypted to ensure participants' privacy. To address potential bias arising from the use of a sequential sampling method, specific measures were implemented. While sequential sampling facilitates efficient recruitment, it may introduce selection bias by favouring patients who are more readily available or accessible. To minimize this risk, efforts were made to ensure diversity within the sample in terms of demographic factors

(such as age, gender, and socioeconomic background), and recruitment was conducted across various times and locations within the clinical setting. Additionally, the research team remained vigilant to prevent the overrepresentation of specific patient subgroups. These steps were undertaken to enhance the generalizability of the study findings and to mitigate any systematic bias associated with the sampling approach.

### 2.5 Statistical Analysis

Data analysis in this study will be conducted using jamovi statistical software. The qualitative data collected will be descriptively analysed to present the demographic and clinical profile of the study sample. In the descriptive analysis, frequency distribution and percentage of each of the studied variables will be analysed using univariate analysis. Subsequently, simple comparisons will be made to compare specific risk factors to DFU recurrence. Data analysis will be performed using cross-tabulations and chi-square tests for categorical variables, while for continuous variables, either independent sample t-test or Mann-Whitney tests will be applied. Logistic regression and other multivariate analyses will be employed to identify the independent predictor factors for the recurrence of DFU after adjustment has been made for confounding factors.

## 3. Results

### 3.1 Demographic of the Sample

This study involved 53 patients with diabetes mellitus who had experienced recurrent diabetic foot ulcers (DFUs) in the Sorong Regency and City, Southwest Papua, Indonesia. The demographic characteristics of the patients were as follows: the mean age of the study participants was 58.4 years ( $\pm$  SD 7.2). Of the 53 participants, 29 (54.7%) were male and 24 (45.3%) were female. Regarding body mass index (BMI), 20 (37.7%) of the participants were either underweight or normal weight (BMI 18.5-24.9), 16 (30.2%) were overweight (BMI 25-29.9), and 32.1% were obese (BMI  $\geq$ 30). These data are presented in the cross-tabulations in [Table 1] below.

### 3.2 Overview of Risk Factors in Patients with Diabetic Foot Ulcer

This cross-sectional study identifies several significant aspects of risk factors predisposing the recurrence of diabetic foot ulcer in Sorong Regency and City, Southwest Papua, Indonesia. Of relevance to this article, participants exhibited a mean HbA1c of  $8.3 \pm 1.4$ , indicating poor glycemic control within the population. Most patients presented with significant vascular disease, manifested as peripheral artery disease 37(69.8%), peripheral neuropathy 41(77.4%), and/or microangiopathy 35(66%). Furthermore, the participants had long-standing diabetes with an average duration of 12.5 years; a substantial proportion had undergone previous amputation 25(47.2%), the majority were smokers 30(56.6%), and many demonstrated irregular dietary habits 39(73.6%). Data is presented in [Table 2] below.

Table 1: Demographic of the Sample

Variable	n	Mean (±SD) / (%)
Age (years)	53	58.4 ± 7.2
Gender		
Male	29	54.7
Female	24	45.3
Body Mass Index		
- Normal (18.5-24.9)	20	37.7
- Overweight (25-29.9)	16	30.2
- Obese (≥30)	17	32.1

Table 2. clinical characteristics of the sample

Variable	n	Mean (±SD) / (%)
Metabolic and Glycaemic Risk Factors		
Haemoglobin A1c (HbA1c) (%)	53	8.3 ± 1.4
Glycaemic Imbalance		
Normal	14	26.4
Blood Sugar Imbalance	39	73.6
Diabetes Control		
Good Diabetes Control (HbA1c < 7.5%)	32	60.4
Poor Diabetes Control (HbA1c > 7.5%)	21	39.6
Glycaemic Control		
Good Glycaemic Control	29	54.7
Poor Glycaemic Control	24	45.3
Vascular Risk Factors		
Peripheral Arterial Disease (PAD)		
No	16	30.2
Yes	37	69.8
Peripheral Neuropathy		
No	12	22.6
Yes	41	77.4
Microangiopathy (Diabetic Retinopathy)		
No	18	34
Yes	35	66
Peripheral Neuropathy		
No	20	37.7
Yes	33	62.3
Microcirculatory Disorders		
No	17	32.1
Yes	36	67.9
Cholesterol (mg/dL)		
Average low-density lipoprotein (LDL)	123.6 ± 28.5	
Average High-density lipoprotein (HDL)	56.4 ± 14.3	
Creatinine (mg/dL)		
Average	1.1 ± 0.3	
Total Bilirubin (mg/dL)		
Average	0.8 ± 0.2	
Urine Albumin-Creatinine Ratio (UACR)		
Normal	19	35.8
Abnormal	34	64.2
Disease Duration and History Risk Factors		
Duration of Diabetes (years)	53	12.5 ± 4.3
Duration of Hospitalization (days)	53	5.8 ± 3.2
Duration of Previous Diabetic Foot Ulcers (weeks)	53	8.7 ± 2.6
History of Amputation		
No	28	52.8
Yes	25	47.2
History of Cardio-cerebrovascular Disease		
No	21	39.6
Yes	32	60.4

Table 2. continued.

Health and Behavioural Risk Factors		
Smoking		
No	23	43.4
Yes	30	56.6
Physical Activity		
Inactive	18	34
Active	35	66
Dietary Patterns		
Healthy	14	26.4
Unhealthy	39	73.6
Walking Impairment		
No	24	45.3
Yes	29	54.7
Wound Healing Knowledge		
Good	18	34
Poor	35	66
Infrequent Blood Glucose Monitoring		
No	19	35.8
Yes	34	64.2
Employment Status		
Unemployed	13	24.5
Employed	40	75.5
Solitary Living		
No	27	50.9
Yes	26	49.1
Low Socioeconomic Status		
No	21	39.6
Yes	32	60.4
Hypertension		
No	18	34
Yes	35	66
Dyslipidaemia		
No	16	30.2
Yes	37	69.8
Morphological and Anatomical Risk Factors		
Foot Deformities		
No	19	35.8
Yes	34	64.2
Charcot's Foot		
No	25	47.2
Yes	28	52.8
Plantar Ulcers		
No	18	34
Yes	35	66
Wound Location		
Toes	16	30.2
Sole	37	69.8
Prominent Metatarsal Head (MTH)		
No	21	39.6
Yes	32	60.4
Management and Care Risk Factors		
Foot Care		
Inadequate	25	47.2
Adequate	28	52.8
Presence of Minor Lesions		
No	23	43.4
Yes	30	56.6
Monofilament Test		
Not Conducted	20	37.7
Conducted	33	62.3

Table 2. continued.

Wound, Ischemia, and Foot Infection (WIFI) Stage		
1	18	34
2	35	66
Initial Ulcer Size		
≤ 2 cm	19	35.8
> 2 cm	34	64.2
Wagner Ulcer Grade		
1	25	47.2
2	28	52.8
Wound Healing Time		
≤ 6 weeks	23	43.4
> 6 weeks	30	56.6
History using Ultrasound Assessment		
Not Conducted	19	35.8
Conducted	34	64.2

**Table 3.** Relationship of Risk Factors Contributing to the Recurrence of Diabetic Foot Ulcers

VARIABLE	Non-recurrence (n=27)	Recurrence (n=26)	Mean, (SD)	OR (95% CI)	t-value	p-value
<b>Metabolic and Glycaemic RiskFactors</b>						
Haemoglobin A1c (HbA1c)	7.2 (1.2)	8.5 (1.4)	1.3(0.4)		3.96	<0.001
Glycaemic Imbalance	8 (29.6%)	22 (84.6%)		10.5 (2.14-51.62)		0.003
Poor Diabetes Control (HbA1c > 7.5%)	5 (18.5%)	20 (76.9%)		11.25 (2.78-45.51)		<0.001
Poor Glycaemic Control	10 (37.0%)	23 (88.5%)		12 (2.67-53.98)		<0.001
<b>Vascular Risk Factors</b>						
Total Bilirubin (mg/dL)	0.9 (0.2)	1.2 (0.3)	0.3 (0.1)	2.3 (1.30-4.10)	2.35	0.02*
Microcirculatory Disorders	5 (18.5%)	18 (69.2%)		10.2 (2.46-42.32)		0.001
How-density lipoprotein (HDL) (mg/dL)	45.2 (12.3)	39.8 (10.5)	-5.4 (3.2)		1.69	0.096
Availability of Glucose MeasuringDevices	16 (59.3%)	8 (30.8%)		0.30 (0.10-0.89)		0.035
Cholesterol (mg/dL)	195 (18.0)	210 (20.0)	15 (2.0)	1.5 (0.90-2.50)	1.75	00.08
Creatinine (mg/dL)	1.1 (0.3)	1.4 (0.4)	0.3 (0.1)	2.1 (1.20-3.70)	2.10	0.04*
Low-density lipoprotein (LDL) (mg/dL)	120.4 (30.2)	135.6 (35.4)	15.2 (8.4)		1.80	0.078
Microangiopathy (Diabetic Retinopathy)	8 (29.6%)	21 (80.8%)		10.33 (2.30-46.51)		<0.001
Peripheral Neuropathy	6 (22.2%)	19 (73.1%)		8.5 (1.92-37.57)		0.004
Peripheral Arterial Disease (PAD)	7 (25.9%)	21 (80.8%)		11.67 (2.61-52.21)		<0.001
Peripheral Neuropathy	6 (22.2%)	19 (73.1%)		8.5 (1.92-37.57)		0.004
Urine Albumin-Creatinine Ratio(UACR)	20 (5.0)	35 (7.0)	15 (2.0)	2 (1.10-3.60)	2.20	0.03*
<b>Duration and Disease History Risk Factors</b>						
Duration of Diabetes	9.6 (5.2)	13.8 (4.3)	2.4 (0.4)		3.61	<0.001
Duration of Hospitalization	15.2 (7.8)	19.5 (6.3)	2.9 (0.4)		3.14	0.003
Duration of Previous Diabetic FootUlcers	2 (7.4%)	17 (65.4%)		25 (4.90-127.35)		<0.001
Knowledge of Wound Healing	3.4 (1.0)	2.8 (0.9)	-0.6 (0.3)		1.92	0.059
History of Amputation	4 (14.8%)	18 (69.2%)		14 (3.31-59.21)		<0.001
History of Cardio-cerebrovascularDisease	7 (25.9%)	19 (73.1%)		8.5 (1.92-37.57)		0.004
<b>Health and Behavioural Risk Factors</b>						
Inactive Physical Activity	3.6 (1.2)	2.2 (0.8)	-1.1 (0.1)		-3.98	<0.001
Dyslipidaemia	12 (44.4%)	18 (69.2%)		2.86 (1.01 -8.06)		0.048
Walking Impairment	6 (22.2%)	19 (73.1%)		8.5 (1.92-37.57)		0.004
Hypertension	16 (59.3%)	21 (80.8%)		2.94 (0.91 -9.48)		0.072
Solitary Living	10 (37.0%)	14 (53.8%)		1.94 (0.67 -5.59)		0.225
Low Socioeconomic Status	17 (65.4%)	11 (40.7%)		2.80 (0.98 -8.00)		0.054
Smoking	10 (37.0%)	23 (88.5%)		12 (2.67-53.98)		<0.001
Employment Status	14 (51.9%)	19 (73.1%)		2.50 (0.84 -7.41)		0.099
Infrequent Blood Glucose Monitoring	10 (37.0%)	15 (57.7%)		2.28 (0.77 -6.77)		0.138
Unhealthy Dietary Patterns	9 (33.3%)	20 (76.9%)		7.5 (1.72-32.72)		0.006
<b>Morphological and Anatomical RiskFactors</b>						
Charcot's Foot	2 (7.4%)	17 (65.4%)		25 (4.90-127.35)		<0.001
Foot Deformities	8 (29.6%)	21 (80.8%)		10.33 (2.30-46.51)		<0.001
Prominent Metatarsal Head (MTH)	7 (25.9%)	19 (73.1%)		8.5(1.92-37.57)		0.004
Wound Location	8 (29.6%)	21 (80.8%)		10.33 (2.30-46.51)		<0.001
Plantar Ulcers	5 (18.5%)	18 (69.2%)		9 (2.14-37.96)		0.002
<b>Management and Care Risk Factors</b>						
History Assessment UsingUltrasonography	8 (29.6%)	21 (80.8%)		10.33 (2.30-46.51)		<0.001
Foot Care	7 (25.9%)	21 (80.8%)		11.67 (2.61-52.21)		<0.001
Presence of Minor Lesions	6 (22.2%)	19 (73.1%)		8.5 (1.92-37.57)		0.004
History assessment usingMonofilament Test	6 (22.2%)	19 (73.1%)		8.5 (1.92-37.57)		0.004
Wound, Ischemia, and Foot Infection(WIFI) Stage	8 (29.6%)	21 (80.8%)		10.33 (2.30-46.51)		<0.001
Initial Ulcer Size	2.3 (0.9)	3.5 (1.2)		2.96 (1.01-8.70)		4.56
Wagner Ulcer Grade	2.1 (0.8)	2.8 (0.7)	0.7 (0.2)		3.06	0.003
Healing Time (weeks)	8.2 (2.1)	12.6 (3.4)	4.4 (1.5)		6.05	<0.001
<b>Demographic and Physical RiskFactors</b>						
Body Mass Index (BMI)	28.3 (3.1)	31.5 (3.4)	3.8 (0.7)		5.24	<0.001
Male	13 (48.1%)	16 (61.5%)		1.75 (0.55-5.60)		0.345
Female	14 (51.9%)	10 (38.5%)		0.57 (0.18-1.83)		0.345
Family History of Diabetes	8 (29.6%)	21 (80.8%)		10.33 (2.30-46.51)		<0.001
Age	61.4 (7.2)	65.8 (6.5)	5.6 (0.5)		3.61	<0.001

Note: A p-value < 0.05 is considered statistically significant.

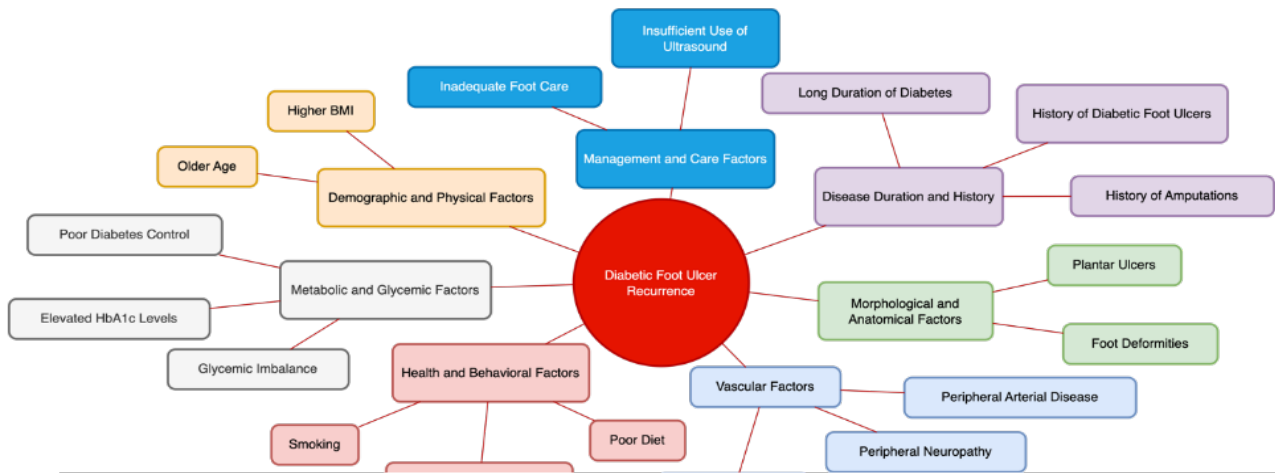


Figure 1. Comprehensive Risk factors for Diabetic Foot Ulcer Recurrence: Multifactorial Analysis



### 3.3 The Relationship between Each Risk Factor and the Recurrence of Diabetic Foot Ulcers

In the present study, the influence of multiple risk factors on the recurrence of diabetic foot ulcers was investigated. These factors encompassed metabolic and glycaemic parameters, vascular duration and disease history, health and behavioural aspects, morphological and anatomical characteristics, management and care practices, and demographic and physical attributes. Statistical analyses were employed to compare patients within each category to those without ulcer recurrence, estimating the associations between the two groups. A summary of the findings is presented in [Table 3] below:

The results presented in [Table 3] indicate that metabolic and glycaemic risk factors, including elevated HbA1c and glycaemic imbalance, demonstrate a significant association with the recurrence of diabetic foot ulcers. Serum total bilirubin and microcirculation abnormalities are additional established vascular factors that exhibit a significant correlation with ulcer recurrence. Moreover, diabetes duration and disease history, as well as health and behavioural risk factors such as physical activity and smoking status, were identified as influencing the reoccurrence of diabetic foot ulcers. Further risk factors that established a relationship with ulcer recurrence include morphological and anatomical factors comprising foot deformities and ulcer site, as well as management and care factors.

### 3.4 Significant Independent Predictors of Diabetic Foot Ulcer Recurrence

This prompted the researchers to employ logistic regression in determining the multiple contributions of various risk factors to the development of diabetic foot ulcers. The examined risk factors encompassed metabolic and glycaemic aspects, vascular status, duration and history of the disease, health-promoting behaviours, morphology, anatomy, management and treatment, as well as demographic and physical profiles. This information is summarized in [Table 4] available below.

As depicted in [Table 4] below, the results of the logistic regression analysis reveal statistically significant independent risk factors that can be utilized to predict the recurrence of diabetic foot ulcers (DFU). These factors encompass glycated haemoglobin (HbA1c), poorly controlled diabetes (HbA1c > 7.5%), cholesterol concentration, low-density lipoprotein (LDL) concentration, peripheral arterial disease (PAD), peripheral neuropathy, disease duration, previous foot ulcer duration, wound healing knowledge, amputation history, cardio-cerebrovascular disease, dyslipidaemia, hypotension history, smoking habits, and plantar ulcers. These findings indicate that poor glycaemic control, vascular and neurological complications, disease duration, previous ulcer history, wound healing knowledge, and smoking cessation are

significant predictors of diabetic foot ulcer recurrence. The findings are summarized in Figure 1.

## 4. Discussion

This study primarily focuses on diabetic foot ulcers (DFUs), a severe complication of diabetes mellitus that significantly impairs patients' quality of life. The potential predictors of DFU recurrence encompass metabolic, vascular, disease progression, behavioural, management, and demographic factors (Huang et al., 2019; Rus et al., 2023).

Metabolic factors, particularly HbA1c levels and glycaemic dysregulation, have been identified as key modifiable predictors in DFU recurrence. Previous research consistently supports these findings, demonstrating that poor glycaemic control significantly elevates the risk for DFU complications (Al-Rubeaan et al., 2015; Ansari et al., 2022; Dekker et al., 2016; Ewid et al., 2023; Hsu et al., 2024; Kidie et al., 2022; Mader et al., 2019; Poonoosamy et al., 2023; Stancu et al., 2023; Xiang et al., 2019; Yazdanpanah et al., 2018). This aligns with studies conducted in resource-limited settings where access to diabetes management is often compromised, leading to higher rates of DFUs (Burgess et al., 2021). For instance, (Al-Rubeaan et al., 2015) reported similar trends in Saudi Arabia, emphasizing the necessity for improved glycaemic control in populations with limited healthcare resources.

In addition to metabolic factors, vascular complications such as peripheral artery disease (PAD) and peripheral neuropathy are significant contributors to DFU recurrence. Research by (Baig et al., 2022) and (Ogurtsova et al., 2021) corroborates these findings, indicating that PAD and neuropathy are critical predictors of DFU recurrence. This is particularly relevant in tropical climates like Sorong, where environmental factors may exacerbate vascular health issues.

The duration of diabetes and related disease history also play crucial roles in determining DFU recurrence rates. (Bundó et al., 2023) observed a higher recurrence risk among patients with longer diabetes durations. However, our study indicates that this relationship is not always linear and may vary based on individual health management practices and overall health status.

Lifestyle factors such as smoking habits, physical activity levels, and dietary choices significantly influence diabetes management and offer protection against complications. Structural abnormalities like foot deformities and plantar ulcers impede prevention efforts by exerting pressure on the feet. Effective foot management practices, including regular monitoring and treatment of foot ulcers, are essential to mitigate recurrence risks.

Demographic factors such as age and body mass index (BMI) present additional challenges in managing risk within this population. Existing literature consistently supports the effectiveness of these factors in managing DFUs. However, some

studies have reported inconclusive data regarding the impact of specific demographic characteristics on DFU recurrence.

The findings of this study indicate a strong association between metabolic and vascular variables and DFU recurrence rates. Elevated HbA1c levels, metabolic acidosis, and PAD emerged as the most significant predictors of recurrence. Notably, this study highlights the strong independent association between HbA1c levels and DFU recurrence risk, emphasizing the necessity for maintaining near-normal blood glucose levels in patients with DFUs. The implications of these identified risk factors for clinical practice are substantial. Healthcare providers in Sorong can implement targeted interventions to address these issues effectively. For instance:

**Enhanced Glycaemic Control:** Providers should prioritize strategies to improve glycaemic control among patients through education on diet management, medication adherence, and regular monitoring of blood glucose levels.

**Vascular Health Management:** Regular screening for PAD and peripheral neuropathy should be incorporated into routine diabetes care protocols to identify at-risk patients early.

**Behavioural Interventions:** Smoking cessation programs and lifestyle modification initiatives should be emphasized to reduce recurrence risks associated with behavioural factors.

**Foot Care Education:** Implementing structured foot care education programs can enable patients to manage their foot health proactively.

**Community-Based Interventions:** Given the unique challenges faced in resource-limited settings like Sorong, community health programs that focus on diabetes education and prevention strategies could significantly reduce DFU recurrence rates.

While this study provides valuable insights into the risk factors associated with DFU recurrence in Sorong, it is imperative to acknowledge its limitations. Data collection methodologies and challenges in assessing specific variables may influence the findings. Therefore, further research is warranted to validate these results and explore effective prevention strategies tailored to diverse demographic contexts. In conclusion, this study contributes to a more comprehensive understanding of the risk factors associated with DFU recurrence in Sorong, Southwest Papua. The results underscore the necessity for a multifaceted approach to DFU treatment that considers local epidemiological characteristics. Future investigations should focus on specific interventions aimed at controlling identified risk factors while providing additional guidance for potential prevention programs across various spatial and temporal contexts.

## Conclusion

This multicentre cross-sectional study's comprehensive analysis of modifiable socio-diagnostic risk factors confirms the high

prevalence of DFUs and their associated risk factors among the study population residing in Sorong Regency and City, Southwest Papua, Indonesia. In accordance with our hypotheses, we demonstrated that metabolic and vascular indices, particularly HbA1c and PAD, play crucial roles in predicting the risk of subsequent DFU development. These risks are exacerbated by behavioural factors, including smoking and physical inactivity, thus necessitating targeted lifestyle modification interventions. Furthermore, the study illustrates that neglecting foot care and failure to conduct routine ultrasonography are two factors that increase recurrence, emphasizing the need for integrated approaches. This is compounded by demographic and physical characteristics such as age and BMI, typically requiring individualized strategies for patients. Concurrently, these findings align with established research while contributing methodologically novel data on the demographic and epidemiological profile of the population in Sorong. Therefore, increasing adherence to GL, improving the management of vascular and neurological DFU complications, and promoting healthier lifestyles are essential in preventing DFU recurrence. The findings from this study have implications for designing intervention strategies and for practicing clinicians and health policymakers to enhance patient care in the region, with the aim of improving patients' quality of life. Additional studies are necessary to replicate these findings and to better identify prevention solutions tailored to the geographical and demographic characteristics of the samples.

## Author contributions

A.C.M. conceptualized the study, developed the methodology, curated the data, and wrote the original draft. E.S. conducted formal analysis, administered the project, supervised, and validated the work. D.N.B. reviewed and edited the writing, investigated, developed the software, and acquired funding and resources.

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## Competing financial interests

The authors have no conflict of interest.

## References

- Ababneh, A., Finlayson, K., Edwards, H., & Lazzarini, P. A. (2022). Factors associated with adherence to using removable cast walker treatment among patients with diabetes-related foot ulcers. *BMJ Open Diabetes Research and Care*, 10(1), e002640. <https://doi.org/10.1136/bmjdr-2021-002640>
- Abdalla, M. M. I., Mohanraj, J., & Somanath, S. D. (2023). Adiponectin as a therapeutic target for diabetic foot ulcer. In *World journal of diabetes* (Vol. 14, Issue 6, pp. 758–782). <https://doi.org/10.4239/wjd.v14.i6.758>
- Afonso, A. C., Oliveira, D., Saavedra, M. J., Borges, A., & Simões, M. (2021). Biofilms in Diabetic Foot Ulcers: Impact, Risk Factors and Control Strategies. *International Journal of Molecular Sciences*, 22(15), Article 15. <https://doi.org/10.3390/ijms22158278>
- Alharbi, M. O., & Sulaiman, A. A. (2022). Foot care knowledge, attitude and practices of diabetic patients: A survey in Diabetes health care facility. *Journal of Family Medicine and Primary Care*, 11(7), 3816. [https://doi.org/10.4103/jfmpc.jfmpc\\_183\\_21](https://doi.org/10.4103/jfmpc.jfmpc_183_21)
- Al-Rubeaan, K., Derwish, M. A., Ouizi, S., Youssef, A., Subhani, S., Ibrahim, H. M., & Alamri, B. N. (2015). Diabetic Foot Complications and Their Risk Factors from a Large Retrospective Cohort Study. <https://doi.org/10.1371/journal.pone.0124446>
- Andrikopoulou, E., Chatzistergos, P., & Chockalingam, N. (2024). Exploring the Pathways of Diabetes Foot Complications Treatment and Investigating Experiences From Frontline Health Care Professionals: Protocol for a Mixed Methods Study. *JMIR Research Protocols*, 13(1), e54852. <https://doi.org/10.2196/54852>
- Ansari, P., Akther, S., Khan, J. T., Islam, S. S., Masud, M. S. R., Rahman, A., Seidel, V., & Abdel-Wahab, Y. H. A. (2022). Hyperglycaemia-Linked Diabetic Foot Complications and Their Management Using Conventional and Alternative Therapies. *Applied Sciences*, 12(22), Article 22. <https://doi.org/10.3390/app122211777>
- Baig, M. S., Banu, A., Zehravi, M., Rana, R., Burle, S. S., Khan, S. L., Islam, F., Siddiqui, F. A., Massoud, E. E. S., Rahman, M. H., & Cavalu, S. (2022). An Overview of Diabetic Foot Ulcers and Associated Problems with Special Emphasis on Treatments with Antimicrobials. *Life*, 12(7), Article 7. <https://doi.org/10.3390/life12071054>
- Banik, P. C., Barua, L., Moniruzzaman, M., Mondal, R., Zaman, F., & Ali, L. (2020). Risk of diabetic foot ulcer and its associated factors among Bangladeshi subjects: A multicentric cross-sectional study. *BMJ Open*, 10(2), e034058. <https://doi.org/10.1136/bmjopen-2019-034058>
- Bezerra, A., Fonseca, H., Rodrigues, F., Delerue-Matos, C., Gouvinhas, I., & Garcia, J. (2023). Honey Therapy in Diabetic Foot Ulcers: A Promising Strategy for Effective Wound Healing. *Applied Sciences*, 13(23), Article 23. <https://doi.org/10.3390/app132312820>
- BKPK, H. (2023, July 15). SKI 2023 Sebagai Tolok Ukur Capaian Kesehatan Nasional. Badan Kebijakan Pembangunan Kesehatan | BPKP Kemenkes. <https://www.badankebijakan.kemkes.go.id/ski-2023-sebagai-tolok-ukur-capaian-kesehatan-nasional/>
- Bonnet, J.-B., & Sultan, A. (2022). Narrative Review of the Relationship Between CKD and Diabetic Foot Ulcer. *Kidney International Reports*, 7(3), 381–388. <https://doi.org/10.1016/j.ekir.2021.12.018>
- Brousseau-Foley, M., & Blanchette, V. (2020). Multidisciplinary Management of Diabetic Foot Ulcers in Primary Cares in Quebec: Can We Do Better? *Journal of Multidisciplinary Healthcare*, 13, 381–385. <https://doi.org/10.2147/JMDH.S251236>
- Bundó, M., Vlachó, B., Llussà, J., Bobé, I., Aivar, M., Círia, C., Martínez-Sánchez, A., Real, J., Mata-Cases, M., Cos, X., Dòria, M., Viade, J., Franch-Nadal, J., & Mauricio, D. (2023). Prediction of outcomes in subjects with type 2 diabetes and diabetic foot ulcers in Catalanian primary care centers: A multicenter observational study. *Journal of Foot and Ankle Research*, 16(1), 8. <https://doi.org/10.1186/s13047-023-00602-6>
- Chen, L., Sun, S., Gao, Y., & Ran, X. (2023). Global mortality of diabetic foot ulcer: A systematic review and meta-analysis of observational studies. *Diabetes, Obesity and Metabolism*, 25(1), 36–45. <https://doi.org/10.1111/dom.14840>
- Choudhury, A. A., & Devi Rajeswari, V. (2021). Gestational diabetes mellitus—A metabolic and reproductive disorder. *Biomedicine & Pharmacotherapy*, 143, 112183. <https://doi.org/10.1016/j.biopha.2021.112183>
- Costa, D., Ielapi, N., Caprino, F., Giannotta, N., Sisinni, A., Abramo, A., Ssempijja, L., Andreucci, M., Bracale, U. M., & Serra, R. (2022). Social Aspects of Diabetic Foot: A Scoping Review. *Social Sciences*, 11(4), Article 4. <https://doi.org/10.3390/socsci11040149>
- Dekker, R. G., Qin, C., Ho, B., & Kadakia, A. (2016). The effect of cumulative glycemic burden on the incidence of diabetic foot disease. <https://doi.org/10.1186/s13018-016-0474-y>
- Deng, L., Xie, P., Chen, Y., Rui, S., Yang, C., Deng, B., Wang, M., Armstrong, D. G., Ma, Y., & Deng, W. (2022). Impact of acute hyperglycemic crisis episode on survival in individuals with diabetic foot ulcer using a machine learning approach. *Frontiers in Endocrinology*, 13. <https://doi.org/10.3389/fendo.2022.974063>
- El Hage, R., Knippschild, U., Arnold, T., & Hinterseher, I. (2022). Stem Cell-Based Therapy: A Promising Treatment for Diabetic Foot Ulcer. *Biomedicines*, 10(7), Article 7. <https://doi.org/10.3390/biomedicines10071507>
- Ewid, M., Algoblan, A. S., Elzaki, E. M., Muqresh, M. A., Al Khalifa, A. R., Alshargabi, A. M., Alotaibi, S. A., Alfayez, A. S., & Naguib, M. (2023). Factors associated with glycemic control and diabetes complications in a group of Saudi patients with type 2 diabetes. *Medicine*, 102(38), e35212. <https://doi.org/10.1097/MD.00000000000035212>
- Gallagher, K. A., Mills, J. L., Armstrong, D. G., Conte, M. S., Kirsner, R. S., Minc, S. D., Plutzky, J., Southerland, K. W., Tomic-Canic, M., & null, null. (2024). Current Status and Principles for the Treatment and Prevention of Diabetic Foot Ulcers in the Cardiovascular Patient Population: A Scientific Statement From the American Heart Association. *Circulation*, 149(4), e232–e253. <https://doi.org/10.1161/CIR.0000000000001192>
- Guan, H., Wang, Y., Niu, P., Zhang, Y., Zhang, Y., Miao, R., Fang, X., Yin, R., Zhao, S., Liu, J., & Tian, J. (2024). The role of machine learning in advancing diabetic foot: A review. *Frontiers in Endocrinology*, 15. <https://doi.org/10.3389/fendo.2024.1325434>
- Guo, Q., Ying, G., Jing, O., Zhang, Y., Liu, Y., Deng, M., & Long, S. (2022). Influencing factors for the recurrence of diabetic foot ulcers: A meta-analysis. *International Wound Journal*, 20(5), 1762–1775. <https://doi.org/10.1111/iwj.14017>
- Guo, Q., Ying, G., Jing, O., Zhang, Y., Liu, Y., Deng, M., & Long, S. (2023). Influencing factors for the recurrence of diabetic foot ulcers: A meta-analysis. *International Wound Journal*, 20(5), 1762–1775. <https://doi.org/10.1111/iwj.14017>

- Haryanto, H., Oe, M., Kardatun, T., Ramadhaniyati, R., Makmuriana, L., Sari, Y., & Bhakti, W. K. (2024). Risk Factors of Recurrent Diabetic Foot Ulcers Based on the Delphi Method. *Iranian Journal of Nursing and Midwifery Research*, 29(1), 56. [https://doi.org/10.4103/ijnmr.ijnmr\\_391\\_21](https://doi.org/10.4103/ijnmr.ijnmr_391_21)
- Hashempour, R., MirHashemi, S., Mollajafari, F., Damiri, S., ArabAhmadi, A., & Raei, B. (2024). Economic burden of diabetic foot ulcer: A case of Iran. In *BMC health services research* (Vol. 24, Issue 1, p. 363). <https://doi.org/10.1186/s12913-024-10873-9>
- Hicks, C. W., Canner, J. K., Mathioudakis, N., Lippincott, C., Sherman, R. L., & Abularrage, C. J. (2020). Incidence and Risk Factors Associated With Ulcer Recurrence Among Patients With Diabetic Foot Ulcers Treated in a Multidisciplinary Setting. *Journal of Surgical Research*, 246, 243–250. <https://doi.org/10.1016/j.jss.2019.09.025>
- Hossain, Md. J., Al-Mamun, Md., & Islam, Md. R. (2024). Diabetes mellitus, the fastest growing global public health concern: Early detection should be focused. *Health Science Reports*, 7(3), e2004. <https://doi.org/10.1002/hsr2.2004>
- Hsu, L., Li, L., & Poon, L. Y. (2024). Analysis of risk factors of infection in diabetic foot patients. *International Wound Journal*, 21(1), e14411. <https://doi.org/10.1111/iwj.14411>
- Huang, Z., Li, S., Kou, Y., Huang, L., Yu, T., & Hu, A. (2019). Risk factors for the recurrence of diabetic foot ulcers among diabetic patients: A meta-analysis. *International Wound Journal*, 16(6), 1373–1382. <https://doi.org/10.1111/iwj.13200>
- Ibrahim, I., Nuermaitait, Y., Maimaituxun, G., Luo, X., Maimaituxun, M., Akbar, A., Tuexun, K., & Wu, Y. (2024). Neutrophil Extracellular Traps (NETs) Are Associated with Type 2 Diabetes and Diabetic Foot Ulcer Related Amputation: A Prospective Cohort Study. In *Diabetes therapy: Research, treatment and education of diabetes and related disorders* (Vol. 15, Issue 6, pp. 1333–1348). <https://doi.org/10.1007/s13300-024-01579-6>
- Jalilian, M., Ahmadi Sarbarzeh, P., & Oubari, S. (2020). Factors Related to Severity of Diabetic Foot Ulcer: A Systematic Review. *Diabetes, Metabolic Syndrome and Obesity*, 13, 1835–1842. <https://doi.org/10.2147/DMSO.S256243>
- Jeffcoate, W., Boyko, E. J., Game, F., Cowled, P., Senneville, E., & Fritidge, R. (2024). Causes, prevention, and management of diabetes-related foot ulcers. *The Lancet Diabetes & Endocrinology*, 12(7), 472–482. [https://doi.org/10.1016/S2213-8587\(24\)00110-4](https://doi.org/10.1016/S2213-8587(24)00110-4)
- Jeyaraman, K., Berhane, T., Hamilton, M., Chandra, A. P., & Falhammar, H. (2019). Mortality in patients with diabetic foot ulcer: A retrospective study of 513 cases from a single Centre in the Northern Territory of Australia. *BMC Endocrine Disorders*, 19, 1. <https://doi.org/10.1186/s12902-018-0327-2>
- Kidie, A. A., Ayal, B. G., Ayele, T., Fentie, E. A., & Lakew, A. M. (2022). Poor glycemic control and associated factors among pediatric diabetes mellitus patients in northwest Ethiopia, 2020: Facility-based cross sectional retrospective study design. *Scientific Reports*, 12(1), 15664. <https://doi.org/10.1038/s41598-022-19909-8>
- Kropp, M., Golubnitschaja, O., Mazurakova, A., Koklesova, L., Sargheini, N., Vo, T.-T. K. S., de Clerck, E., Polivka, J., Potuznik, P., Polivka, J., Stetkarova, I., Kubatka, P., & Thumann, G. (2023). Diabetic retinopathy as the leading cause of blindness and early predictor of cascading complications—Risks and mitigation. *EPMA Journal*, 14(1), 21–42. <https://doi.org/10.1007/s13167-023-00314-8>
- Lancet, T. (2023). Diabetes: A defining disease of the 21st century. *The Lancet*, 401(10394), 2087. [https://doi.org/10.1016/S0140-6736\(23\)01296-5](https://doi.org/10.1016/S0140-6736(23)01296-5)
- Lee, S. H., Kim, S. H., Kim, K. B., Kim, H. S., & Lee, Y. K. (2024). Factors Influencing Wound Healing in Diabetic Foot Patients. *Medicina*, 60(5), Article 5. <https://doi.org/10.3390/medicina60050723>
- Lo, Z. J., Tan, E., Chandrasekar, S., Ooi, D., Liew, H., Ang, G., Yong, E., Hong, Q., Chew, T., Muhammad Farhan, M. F., Zhu, X., Ang, P., Law, C., Raman, N., Park, D., Tavintharan, S., Hoi, W. H., Lin, J., Koo, H. Y., ... Collaborators, D. C. (2023). Diabetic foot in primary and tertiary (DEFINITE) Care: A health services innovation in coordination of diabetic foot ulcer (DFU) Care within a healthcare cluster - 18-month results from an observational population health cohort study. *International Wound Journal*, 20(5), 1609–1621. <https://doi.org/10.1111/iwj.14016>
- Mader, J. K., Haas, W., Aberer, F., Boulgaropoulos, B., Baumann, P., Pandis, M., Horvath, K., Aziz, F., Köhler, G., Pieber, T. R., Plank, J., & Sourij, H. (2019). Patients with healed diabetic foot ulcer represent a cohort at highest risk for future fatal events. *Scientific Reports*, 9(1), 10325. <https://doi.org/10.1038/s41598-019-46961-8>
- Mashili, F., Joachim, A., Aboud, S., Mchembe, M., Chiwanga, F., Addo, J., Kendall, L., Ako, A., & Abbas, Z. (2019). Prospective exploration of the effect of adiposity and associated microbial factors on healing and progression of diabetic foot ulcers in Tanzania: Study protocol of a longitudinal cohort study. *BMJ Open*, 9(12), e031896. <https://doi.org/10.1136/bmjopen-2019-031896>
- Mustamu, A. C. (2024). Perception and Utilisation of Information and Communication Technology (ICT) in the Management of Diabetes in Children: Insights From Health Students in Indonesia. *Scripta Medica*, 55(1), Article 1. <https://doi.org/10.5937/scriptamed55-46690>
- Mustamu, A. C., Mustamu, H. L., & Hasim, N. H. (2020). PENINGKATAN PENGETAHUAN & SKILL DALAM MERAWAT LUKA. *Jurnal Pengabdian Masyarakat Sasambo*, 1(2), Article 2. <https://doi.org/10.32807/jpms.v1i2.483>
- Ogurtsova, K., Morbach, S., Haastert, B., Dubský, M., Rümenerap, G., Ziegler, D., Jirkovska, A., & Icks, A. (2021). Cumulative long-term recurrence of diabetic foot ulcers in two cohorts from centres in Germany and the Czech Republic. *Diabetes Research and Clinical Practice*, 172, 108621. <https://doi.org/10.1016/j.diabres.2020.108621>
- Ong, K. L., Stafford, L. K., McLaughlin, S. A., Boyko, E. J., Vollset, S. E., Smith, A. E., Dalton, B. E., Duprey, J., Cruz, J. A., Hagins, H., Lindstedt, P. A., Aali, A., Abate, Y. H., Abate, M. D., Abbasian, M., Abbasi-Kangevari, Z., Abbasi-Kangevari, M., ElHafeez, S. A., Abd-Rabu, R., ... Vos, T. (2023). Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: A systematic analysis for the Global Burden of Disease Study 2021. *The Lancet*, 402(10397), 203–234. [https://doi.org/10.1016/S0140-6736\(23\)01301-6](https://doi.org/10.1016/S0140-6736(23)01301-6)
- Piran, N., Farhadian, M., Soltanian, A. R., & Borzouei, S. (2024). Diabetic foot ulcers risk prediction in patients with type 2 diabetes using classifier based on associations rule mining. *Scientific Reports*, 14(1), 635. <https://doi.org/10.1038/s41598-023-47576-w>
- Poonoosamy, J., Lopes, P., Huret, P., Dardari, R., Penfornis, A., Thomas, C., & Dardari, D. (2023). Impact of Intensive Glycemic Treatment on Diabetes Complications—A Systematic Review. *Pharmaceutics*, 15(7), Article 7. <https://doi.org/10.3390/pharmaceutics15071791>

- Popa, A. D., Gavril, R. S., Popa, I. V., Mihalache, L., Gherasim, A., Niță, G., Graur, M., Arhire, L. I., & Niță, O. (2023). Survival Prediction in Diabetic Foot Ulcers: A Machine Learning Approach. *Journal of Clinical Medicine*, 12(18), Article 18. <https://doi.org/10.3390/jcm12185816>
- Rastogi, A., Goyal, G., Kesavan, R., Bal, A., Kumar, H., Mangalanadanam, Kamath, P., Jude, E. B., Armstrong, D. G., & Bhansali, A. (2020). Long term outcomes after incident diabetic foot ulcer: Multicenter large cohort prospective study (EDI-FOCUS investigators) epidemiology of diabetic foot complications study: Epidemiology of diabetic foot complications study. *Diabetes Research and Clinical Practice*, 162, 108113. <https://doi.org/10.1016/j.diabres.2020.108113>
- Rismayanti, I. D. A., Nursalam, Farida, V. N., Dewi, N. W. S., Utami, R., Aris, A., & Agustini, N. L. P. I. B. (2022). Early detection to prevent foot ulceration among type 2 diabetes mellitus patient: A multi-intervention review. *Journal of Public Health Research*, 11(2), 2752. <https://doi.org/10.4081/jphr.2022.2752>
- Rubio, J. A., Jiménez, S., & Lázaro-Martínez, J. L. (2020). Mortality in Patients with Diabetic Foot Ulcers: Causes, Risk Factors, and Their Association with Evolution and Severity of Ulcer. *Journal of Clinical Medicine*, 9(9), 3009. <https://doi.org/10.3390/jcm9093009>
- Ruiz-Muñoz, M., Martínez-Barrios, F.-J., Fernández-Torres, R., Lopezosa-Reca, E., & Marchena-Rodríguez, A. (2024). Autologous platelet-rich plasma (APRP) in diabetes foot disease: A meta-analysis. *Journal of Diabetes and Its Complications*, 38(2), 108690. <https://doi.org/10.1016/j.jdiacomp.2024.108690>
- Rus, M., Crisan, S., Andronie-Cioara, F. L., Indries, M., Marian, P., Pobirci, O. L., & Ardelean, A. I. (2023). Prevalence and Risk Factors of Metabolic Syndrome: A Prospective Study on Cardiovascular Health. *Medicina*, 59(10), Article 10. <https://doi.org/10.3390/medicina59101711>
- Ruze, R., Liu, T., Zou, X., Song, J., Chen, Y., Xu, R., Yin, X., & Xu, Q. (2023). Obesity and type 2 diabetes mellitus: Connections in epidemiology, pathogenesis, and treatments. *Frontiers in Endocrinology*, 14. <https://doi.org/10.3389/fendo.2023.1161521>
- Silva-Tinoco, R., Cuatecontzi-Xochitlotzi, T., Reyes-Paz, Y., Vidal-Santos, B., Galíndez-Fuentes, A., & Castillo-Martínez, L. (2024). Improving foot ulcer risk assessment and identifying associated factors: Results of an initiative enhancing diabetes care in primary settings. *Diabetes Epidemiology and Management*, 14, 100195. <https://doi.org/10.1016/j.deman.2023.100195>
- Søndergaard, S. F., Vestergaard, E. G., Andersen, A. B., Kolbæk, R., Dahl, M., & Høgh, A. (2023). How patients with diabetic foot ulcers experience telemedicine solutions: A scoping review. *International Wound Journal*, 20(5), 1796–1810. <https://doi.org/10.1111/iwj.14026>
- Stancu, B., Ilyés, T., Farcas, M., Coman, H. F., Chiș, B. A., & Andercou, O. A. (2023). Diabetic Foot Complications: A Retrospective Cohort Study. *International Journal of Environmental Research and Public Health*, 20(1), Article 1. <https://doi.org/10.3390/ijerph20010187>
- Stegge, W. B. aan de Schut, M. C., Abu-Hanna, A., Baal, J. G. van, Netten, J. J. van, & Bus, S. A. (2021). Development of a prediction model for foot ulcer recurrence in people with diabetes using easy-to-obtain clinical variables. *BMJ Open Diabetes Research and Care*, 9(1), e002257. <https://doi.org/10.1136/bmjdr-2021-002257>
- Swaminathan, N., Awuah, W. A., Bharadwaj, H. R., Roy, S., Ferreira, T., Adebosoye, F. T., Ismail, I. F. N. binti, Azeem, S., Abdul-Rahman, T., & Papadakis, M. (2024). Early intervention and care for Diabetic Foot Ulcers in Low and Middle Income Countries: Addressing challenges and exploring future strategies: A narrative review. *Health Science Reports*, 7(5), e2075. <https://doi.org/10.1002/hsr2.2075>
- Tan, T.-W., Caldwell, B., Zhang, Y., Kshirsagar, O., Cotter, D. J., & Brewer, T. W. (2024). Foot and Ankle Care by Podiatrists and Amputations in Patients With Diabetes and Kidney Failure. *JAMA Network Open*, 7(3), e240801. <https://doi.org/10.1001/jamanetworkopen.2024.0801>
- Tola, A., Regassa, L. D., & Ayele, Y. (2021). Prevalence and associated factors of diabetic foot ulcers among type 2 diabetic patients attending chronic follow-up clinics at governmental hospitals of Harari Region, Eastern Ethiopia: A 5-year (2013–2017) retrospective study. *SAGE Open Medicine*, 9, 2050312120987385. <https://doi.org/10.1177/2050312120987385>
- Tomic, D., Shaw, J. E., & Magliano, D. J. (2022). The burden and risks of emerging complications of diabetes mellitus. *Nature Reviews Endocrinology*, 18(9), Article 9. <https://doi.org/10.1038/s41574-022-00690-7>
- Tuglo, L. S., Nyande, F. K., Agordoh, P. D., Nartey, E. B., Pan, Z., Logosu, L., Dei-Hlorlewu, A. E., Haligah, D. K., Osafo, L., Taful, S., & Chu, M. (2021). Knowledge and practice of diabetic foot care and the prevalence of diabetic foot ulcers among diabetic patients of selected hospitals in the Volta Region, Ghana. *International Wound Journal*, 19(3), 601–614. <https://doi.org/10.1111/iwj.13656>
- Waibel, F. W. A., Uçkay, I., Soldevila-Boixader, L., Sydler, C., & Gariani, K. (2024). Current knowledge of morbidities and direct costs related to diabetic foot disorders: A literature review. *Frontiers in Endocrinology*, 14. <https://doi.org/10.3389/fendo.2023.1323315>
- Wang, Y., Liu, B., Pi, Y., Hu, L., Yuan, Y., Luo, J., Tao, Y., Li, P., Lu, S., & Song, W. (2022). Risk factors for diabetic foot ulcers mortality and novel negative pressure combined with platelet-rich plasma therapy in the treatment of diabetic foot ulcers. *Frontiers in Pharmacology*, 13. <https://doi.org/10.3389/fphar.2022.1051299>
- Wang, Z., Tan, X., Xue, Y., Xiao, C., Yue, K., Lin, K., Wang, C., Zhou, Q., & Zhang, J. (2024). Smart diabetic foot ulcer scoring system. In *Scientific reports* (Vol. 14, Issue 1, p. 11588). <https://doi.org/10.1038/s41598-024-62076-1>
- Xiang, J., Wang, S., He, Y., Xu, L., Zhang, S., & Tang, Z. (2019). Reasonable Glycemic Control Would Help Wound Healing During the Treatment of Diabetic Foot Ulcers. *Diabetes Therapy*, 10(1), 95–105. <https://doi.org/10.1007/s13300-018-0536-8>
- Xie, J., Wang, M., Long, Z., Ning, H., Li, J., Cao, Y., Liao, Y., Liu, G., Wang, F., & Pan, A. (2022). Global burden of type 2 diabetes in adolescents and young adults, 1990-2019: Systematic analysis of the Global Burden of Disease Study 2019. *BMJ*, 379, e072385. <https://doi.org/10.1136/bmj-2022-072385>
- Xu, J., Gao, J., Li, H., Zhu, Z., Liu, J., & Gao, C. (2024). The risk factors in diabetic foot ulcers and predictive value of prognosis of wound tissue vascular endothelium growth factor. *Scientific Reports*, 14(1), 14120. <https://doi.org/10.1038/s41598-024-64009-4>
- Yazdanpanah, L., Shahbazian, H., Hesam, S., Ahmadi, B., & Zamani, A. M. (2024). Two-year incidence and risk factors of diabetic foot ulcer: Second phase report of Ahvaz

- diabetic foot cohort (ADFC) study. In *BMC endocrine disorders* (Vol. 24, Issue 1, p. 46). <https://doi.org/10.1186/s12902-024-01572-x>
- Yazdanpanah, L., Shahbazian, H., Nazari, I., Arti, H., Ahmadi, F., Mohammadianinejad, S. E., Cheraghian, B., & Hesam, S. (2018). Incidence and Risk Factors of Diabetic Foot Ulcer: A Population-Based Diabetic Foot Cohort (ADFC Study)—Two-Year Follow-Up Study. <https://doi.org/10.1155/2018/7631659>
- Yu, X., Chen, M., Wu, J., & Song, R. (2024). Research progress of SIRT3 activator resveratrol and its derivatives in autoimmune diseases. *Frontiers in Immunology*, 15. <https://doi.org/10.3389/fimmu.2024.1390907>
- Yunir, E., Tahapary, D. L., Tarigan, T. J. E., Harbuwono, D. S., Oktavianda, Y. D., Kristanti, M., Iswati, E., Sarumpaet, A., & Soewondo, P. (2021). Non-vascular contributing factors of diabetic foot ulcer severity in national referral hospital of Indonesia. *Journal of Diabetes and Metabolic Disorders*, 20(1), 805–813. <https://doi.org/10.1007/s40200-021-00827-x>
- Zamani, N., Chung, J., Evans-Hudnall, G., Martin, L. A., Gilani, R., Poythress, E. L., Skelton-Dudley, F., Huggins, J. S., Trautner, B. W., & Mills, J. L. (2021). Engaging patients and caregivers to establish priorities for the management of diabetic foot ulcers. *Journal of Vascular Surgery*, 73(4), 1388-1395.e4. <https://doi.org/10.1016/j.jvs.2020.08.127>