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Nutritional Risk, Frailty, and Inflammatory Biomarkers as Correlates of Infection Severity and Healing Risk in Patients with Diabetic Foot Ulcers: A Hospital-Based Cross-Sectional Study

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Abstract

Background: Diabetic foot ulcers (DFU) remain a major clinical problem because severe infection and poor healing increase hospitalization, amputation, and mortality. Patient-level factors such as nutritional vulnerability, frailty, and inflammatory burden may be clinically relevant, but integrated hospital-based evidence remains limited, particularly in Indonesian wound-care settings.

Aim: To examine whether nutritional risk, frailty, and inflammatory biomarkers were associated with infection severity and healing risk in hospitalized patients with diabetic foot ulcers.

Approach: This hospital-based cross-sectional study included 91 adults with active diabetic foot ulcers at General Hospital Bhakti Rahayu. Consecutive sampling was used. Eligible participants had diabetes, an active ulcer, and complete clinical and laboratory data. Ordinal and binary logistic regression analyses were performed using IBM SPSS Statistics version 19

Results: The mean (SD) age was 58.6 (10.9) years, 62.6% were male, 73.6% had nutritional risk, and 41.8% were frail. Infection severity was mild in 31.9%, moderate in 47.3%, and severe in 20.9%. Higher infection severity was associated with nutritional risk (aOR, 3.18; 95% CI, 1.05-9.67; P = .04), frailty (aOR, 2.24; 95% CI, 1.01-4.98; P = .048), and higher CRP per 10-mg/L increase (aOR, 1.22; 95% CI, 1.05-1.42; P = .01)

Conclusions: Nutritional risk, frailty, and inflammatory burden were associated with greater infection severity in hospitalized patients with diabetic foot ulcers.

Implication for Nursing Practice: Nursing assessment of diabetic foot ulcers may benefit from integrating nutritional screening, frailty evaluation, and inflammatory biomarker review to support earlier risk identification and more individualized wound-care planning.

Keywords: c-reactive protein; diabetic foot; frailty; inflammation mediators; malnutrition; wound healing

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Introduction

Diabetic foot ulcers (DFUs) are an important clinical and public health problem in people with diabetes because they are associated with substantial morbidity, disability, amputation, mortality, and health-care costs (Armstrong et al., 2023; Jeffcoate et al., 2024). Globally, DFUs affect about 18.6 million people each year, the lifetime risk has been estimated at 19%–34%, and approximately 50%–60% of ulcers eventually become infected, which markedly increases the risk of hospitalization, limb loss, and death (Armstrong et al., 2023; Lim et al., 2025). The burden has remained high rather than declining, and long-term prognosis is poor, with pooled survival falling to 50.9% at 5 years and 23.1% at 10 years among patients with DFUs (Chen et al., 2023). In Asia, the problem is particularly relevant because chronic wound prevalence remains high, DFUs are the most common wound type, and prevalence is higher in developing countries (34.8%), Southeast Asia (50.8%), and hospital-based settings (32.6%) (Burhan et al., 2025). In Indonesia, the diabetes burden has increased over the last decade, rising from 10.7% in 2013 to 11.8% in 2018 and remaining 11.3% in 2023, while a multicentre Indonesian DFU cohort showed that although many patients healed, 14% underwent minor amputation, 4% underwent major amputation, and 8% died within 12 months (Muharram et al., 2025; Burhan et al., 2025). Therefore, better understanding of factors linked to infection severity and healing risk in DFUs is important for improving wound care, risk stratification, and clinical outcomes in hospital practice (Jeffcoate et al., 2024).

Previous studies have shown that poor DFU outcomes are strongly related to infection, hyperglycaemia, peripheral arterial disease, renal dysfunction, and inadequate off-loading, indicating that healing is determined not only by local wound treatment but also by systemic patient factors (Burhan et al., 2025; Jeffcoate et al., 2024). Existing evidence also suggests that malnutrition is common in DFUs, with 49%–70% of patients at nutritional risk or 15%–62% already malnourished, and GLIM-based hospital data identified malnutrition in 38.36% of hospitalized DFU patients; malnutrition was linked to lower BMI, hypoalbuminaemia, poor glycaemic control, ulcer infection, impaired ABI, and prolonged hospitalization (Lauwers et al., 2022; Ran et al., 2024). Recent studies have also shown that frailty is clinically relevant in diabetic foot disease: frailty was associated with higher DFU risk and mortality in large diabetes cohorts, and poorer foot-care behaviours and self-efficacy in adults with type 2 diabetes (Neal et al., 2026; Bilici & Kılıç, 2026; Jiao et al., 2025). In parallel, inflammatory biomarkers such as the neutrophil-to-lymphocyte ratio and CRP-to-albumin ratio have emerged as practical indicators of diabetic foot infection severity, while hospital-based wound studies in your table have mainly focused on dressings, topical antimicrobials, wound cleansing, NPWT, and healing trajectories rather than on integrated host vulnerability (Canpolat-Erkan et al., 2026; Burhan et al., 2025; Romano et al., 2025; Srisawat et al., 2025; Burhan et al., 2022). However, those studies have been limited by a predominant focus on intervention effectiveness or single prognostic domains, and by the lack of a unified assessment of nutritional risk, frailty, and inflammatory burden in the same hospitalized DFU population (Burhan et al., 2025; Burhan et al., 2025).

Little is known about how nutritional risk, frailty, and inflammatory biomarkers jointly relate to infection severity and healing risk in patients hospitalized with DFUs in Indonesian clinical settings. This is important because infection severity and healing vulnerability are not determined by the wound alone; they are shaped by systemic inflammation, nutritional reserve, vascular compromise, functional decline, and the patient's capacity to respond to physiological stress (Jeffcoate et al., 2024; Canpolat-Erkan et al., 2026). In particular, it remains unclear whether patients with higher nutritional risk, greater frailty, and more abnormal inflammatory biomarkers present with more severe infection and a worse healing risk profile at the time of hospital assessment. Prior wound-care studies in your table provide indirect support for this concern: malnutrition was associated with higher chronic wound prevalence in Asia, frailty increased wound burden and severity in older adults with skin tears, infection reduced healing in limb-threatening ischemia, and DFU infection impaired healing in Indonesian and international wound-care cohorts (Burhan et al., 2025; Lindström et al., 2025; Haruka et al., 2025; Burhan et al., 2025). To our knowledge, no hospital-based cross-sectional study at General Hospital Bhakti Rahayu has examined these three host-related domains together as correlates of both infection severity and healing risk in patients with DFUs. Addressing this gap may inform early nursing assessment, multidisciplinary triage, nutritional screening, and biomarker-guided risk stratification in routine DFU care (Armstrong et al., 2023; Jeffcoate et al., 2024).

Recent wound-care evidence has already shown that advanced dressings, topical antimicrobial strategies, wound cleansing approaches, and NPWT can improve local wound outcomes, and that serial oxygen monitoring can refine healing surveillance (Burhan et al., 2025; Srisawat et al., 2025; Romano et al., 2025; Mahendra et al., 2024; Burhan et al., 2022; Haruka et al., 2025). Yet this literature also suggests an important unresolved issue: local wound therapy may be necessary, but it is unlikely to be sufficient when patients simultaneously experience malnutrition, frailty, persistent inflammation, infection, and metabolic dysregulation. In other words, wound care nursing needs a stronger patient-level risk framework that goes beyond the dressing choice and includes the host's nutritional, functional, and inflammatory condition at presentation (Burhan et al., 2025; Burhan et al., 2025; Burhan et al., 2022).

Therefore, the objective of this study was to examine the correlations of nutritional risk, frailty, and inflammatory biomarkers with infection severity and healing risk in patients with diabetic foot ulcers at General Hospital Bhakti Rahayu. In this hospital-based cross-sectional study, we examined adults with active DFUs and assessed host-related risk factors alongside wound-related clinical outcomes. The primary outcomes were infection severity and healing risk, while secondary outcomes included the distribution of nutritional risk, frailty status, and inflammatory biomarker levels in the study population. We hypothesised that higher nutritional risk, greater frailty, and more abnormal inflammatory biomarker profiles would be associated with more severe infection and a higher healing risk profile in patients with DFUs (Canpolat-Erkan et al., 2026; Neal et al., 2026; Ran et al., 2024).

Method

Study Design

This hospital-based cross-sectional study examined the associations of nutritional risk, frailty, and inflammatory biomarkers with infection severity and healing risk among patients with diabetic foot ulcers (DFUs) treated at General Hospital Bhakti Rahayu, Ambon, Maluku, Indonesia, from December 1, 2025, to January 5, 2026. The main objective was to assess whether patient-level nutritional vulnerability, frailty status, and inflammatory burden were associated with more severe diabetic foot infection and a poorer healing-risk profile at the time of hospital assessment. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline for cross-sectional studies. Because this was a single-center observational study with no intervention, the protocol was not prospectively registered (von Elm et al., 2007).

Ethics Approval and Informed Consent

The study protocol was reviewed and approved by the Health Research Ethics Committee of STIKES RS Prof. Dr. J.A. Latumeten, Indonesia, with approval number No. 6774/STK/XI/2025. All participants provided written informed consent before enrollment. No waiver of consent was applied because the study involved direct patient interviews, bedside wound assessment, and use of clinical laboratory data linked to identifiable hospital records.

Setting and Participants

The study was conducted at General Hospital Bhakti Rahayu, a hospital-based wound care setting in Ambon, Maluku, Indonesia. The source population comprised all adult patients with DFUs who were hospitalized or received in-hospital wound care evaluation during the study period. The target population was adults with active DFUs requiring hospital-based assessment and management. Recruitment and data collection were performed continuously during the study period, and each participant was assessed once during the index hospitalization, generally within the first 24 hours after eligibility confirmation.

Eligibility Criteria and Sampling

Eligible participants were adults aged 18 years or older with a documented diagnosis of diabetes mellitus and an active diabetic foot ulcer located below the malleoli, confirmed clinically by the treating team in accordance with contemporary diabetes-related foot disease guidance (Schaper et al., 2024; Armstrong et al., 2023). Participants were also required to be clinically stable enough to complete the interview and undergo bedside assessment, and to have available routine laboratory results for complete blood count, C-reactive protein, and serum albumin obtained during the hospital evaluation. Patients were excluded if they had non-diabetic foot wounds, isolated postoperative wounds without DFU, severe cognitive or communication impairment that prevented valid questionnaire completion, or incomplete primary exposure or outcome data. A consecutive sampling approach was used; all eligible patients presenting during the study period were approached for participation. Among the accessible population of 110 patients, 91 had complete analytic data and were included in the final analysis (Schaper et al., 2024; Armstrong et al., 2023).

Sample Size

The required minimum sample size was estimated using the single-population proportion formula with finite population correction because the accessible source population during the study period was fixed at 110 patients. The proportion was taken from a recent cross-sectional diabetic foot study in which malnutrition, based on the GLIM framework, was identified in 39.68% of patients, making it the most relevant prior estimate for the nutritional-risk domain of the present study (Ran et al., 2025). Using a 95% confidence level, an absolute precision of 5%, and a source population of 110, the corrected minimum sample size was 85 participants. Because all eligible patients during the study period were recruited consecutively, and 91 participants had complete data, the final analytic sample exceeded the minimum requirement (Ran et al., 2025).

Variables

The primary outcome was infection severity, classified using the International Working Group on the Diabetic Foot/Infectious Diseases Society of America framework incorporated in PEDIS-based infection grading. Infection severity was categorized clinically as mild, moderate, or severe according to the extent of local infection, depth of tissue involvement, and presence of systemic inflammatory manifestations (Senneville et al., 2024). The secondary outcome was healing risk, operationalized using the SINBAD score as a structured indicator of poor-healing vulnerability; a higher score reflected greater risk, and a score of 3 or higher was considered high healing risk based on recent prospective diabetic foot evidence (Kunda et al., 2025). The main exposure variables were nutritional risk, frailty, C-reactive protein (CRP), neutrophil-to-lymphocyte ratio (NLR), and CRP-to-albumin ratio (CAR). Potential covariates selected a priori on clinical grounds were age, sex, body mass index, education, smoking history, diabetes duration, diabetes treatment, hypertension, ulcer duration, previous ulcer history, previous amputation history, and glycated hemoglobin (HbA1c) (Senneville et al., 2024; Kunda et al., 2025).

Data Sources and Measurement

Data were obtained from interviewer-administered questionnaires, bedside clinical examination, hospital medical records, and routine laboratory tests. All measurements were collected once per participant during the study visit. Questionnaire data were obtained through face-to-face interviews by trained nurse investigators using a standardized case-report form. Clinical wound assessments were performed at the bedside by trained nurses and verified against the treating clinician's notes. Laboratory parameters were extracted from same-episode hospital tests processed by the clinical laboratory under routine quality-control procedures. Before data collection, the research team underwent standardized training on informed consent procedures, questionnaire administration, wound grading, and completion of the study form to improve measurement consistency.

Demographic and Clinical Characteristics

Demographic and background clinical data were recorded in one standardized paragraph-based case-report form and included age, sex, education level, marital status, occupation, smoking history, alcohol use, body mass index, diabetes duration, diabetes treatment, hypertension, blood pressure, ulcer duration, prior ulcer history, prior amputation history, ulcer site, and HbA1c. Age, sex, education, smoking, alcohol use, and diabetes history were obtained by interview and cross-checked against the medical record. Weight and height were measured using a calibrated digital scale and stadiometer when feasible, and body mass index was calculated as weight in kilograms divided by height in meters squared. Blood pressure was measured with an automated sphygmomanometer after a short seated rest period. HbA1c and other biochemical data were abstracted from the index hospital laboratory record.

Assessment of Nutritional Risk

Assessment of Nutritional Risk: Nutritional risk was assessed using the Mini Nutritional Assessment–Short Form (MNA-SF), a 6-item screening instrument that evaluates recent food intake, weight loss, mobility, psychological stress or acute illness, neuropsychological problems, and body mass index or calf circumference. The MNA-SF was administered once at enrollment by interviewer-assisted questioning and bedside anthropometry. The total score ranges from 0 to 14, with 12–14 indicating normal nutritional status, 8–11 indicating risk of malnutrition, and 0–7 indicating malnutrition. For the present study, nutritional risk was defined as an MNA-SF score of 11 or lower. In diabetic foot populations, the MNA-SF has shown stronger agreement with GLIM-defined malnutrition than NRS-2002, with sensitivity of 89.8%, specificity of 79.2%, and area under the curve of 0.860, supporting its use in this population (Ran et al., 2025).

Assessment of Frailty

Assessment of Frailty: Frailty was assessed using the Groningen Frailty Indicator (GFI), a multidomain 15-item instrument that captures physical, cognitive, social, and psychological vulnerability. The GFI was administered once at enrollment in interviewer-assisted format because some hospitalized patients had reduced mobility or reading tolerance. Item scores were summed to obtain a total score from 0 to 15, with higher scores indicating greater frailty. A score of 4 or higher was used to define frailty in the present study because this threshold is widely used in clinical frailty research, while recent validation work showed that a cut point of 3 yielded sensitivity of 88.2% and specificity of 79.6% for frailty screening and that internal consistency ranged from Cronbach α 0.759 to 0.87 across recent validation studies (Huang et al., 2022; Midao et al., 2025).

Assessment of C-Reactive Protein

Assessment of C-Reactive Protein: Serum CRP was used as a marker of systemic inflammatory activity and was obtained from routine venous blood collected during the hospital evaluation. CRP was measured in milligrams per liter by the hospital clinical laboratory using standard biochemical procedures and recorded once for each participant from the index assessment. For descriptive purposes, CRP values above 10 mg/L were considered elevated inflammatory activity; however, CRP was analyzed as a continuous variable in regression models to preserve information and avoid arbitrary categorization. Recent diabetic foot infection research reported that CRP had excellent discriminatory performance for infected diabetic foot status, with an area under the curve of 0.902, supporting its clinical relevance in severity stratification (Canpolat-Erkan et al., 2026).

Assessment of Neutrophil-to-Lymphocyte Ratio

Assessment of Neutrophil-to-Lymphocyte Ratio: NLR was calculated from the same complete blood count obtained during the index hospital assessment by dividing the absolute neutrophil count by the absolute lymphocyte count. This ratio was recorded once per participant and analyzed as a continuous biomarker because no universally accepted DFU-specific threshold has been established for routine clinical categorization. NLR was selected because it is inexpensive, rapidly available, and biologically reflects the balance between innate inflammatory activation and adaptive immune suppression. In recent diabetic foot infection data, NLR was significantly associated with PEDIS stage and related inflammatory severity markers, with moderate discriminatory performance (area under the curve 0.702) (Canpolat-Erkan et al., 2026).

Assessment of CRP-to-Albumin Ratio

Assessment of CRP-to-Albumin Ratio: CAR was calculated from the same laboratory episode as serum CRP divided by serum albumin, thereby integrating inflammatory burden and protein-nutritional reserve into a single biomarker. CAR was recorded once per participant and analyzed as a continuous variable because no universally accepted hospital-based DFU cutoff has been established. This index was included because it is clinically plausible in DFUs, where inflammation and malnutrition often coexist. In recent diabetic foot infection research, CAR showed strong correlation with PEDIS stage, osteomyelitis, HbA1c, and other severity indicators, and demonstrated excellent discriminatory performance, with an area under the curve of 0.915 (Canpolat-Erkan et al., 2026).

Assessment of Infection Severity

Assessment of Infection Severity: Infection severity was assessed clinically using the IWGDF/IDSA framework for diabetes-related foot infection. Mild infection was defined as local skin or subcutaneous infection with limited erythema; moderate infection referred to deeper or more extensive infection without systemic inflammatory response; and severe infection referred to infection accompanied by systemic inflammatory manifestations. Grading was performed once at bedside by trained nurse investigators using direct wound examination and chart-supported clinical findings, and uncertain cases were reviewed with the treating clinician. This approach was chosen because it aligns with contemporary international guidance for classification of diabetic foot infection severity (Senneville et al., 2024).

Assessment of Healing Risk

Assessment of Healing Risk: Healing risk was assessed using the SINBAD scoring system, which evaluates six ulcer characteristics: site, ischemia, neuropathy, bacterial infection, area, and depth. Each domain is scored 0 or 1, resulting in a total score from 0 to 6, with higher scores indicating poorer healing potential. The score was completed once at bedside from direct ulcer assessment and available clinical examination data. A SINBAD score of 3 or higher was used to indicate high healing risk because recent prospective evidence showed that higher SINBAD scores were associated with delayed healing, nonhealing, and amputation, whereas lower scores were associated with better healing outcomes (Kunda et al., 2025).

Data Collection Procedure

Eligible patients were identified consecutively during the study period from the hospital wound care and inpatient service. After written informed consent was obtained, each participant underwent a one-time study assessment. Interview-based questionnaires typically required approximately 15 to 20 minutes, bedside wound assessment and clinical verification required about 10 to 15 minutes, and chart and laboratory abstraction required an additional 5 to 10 minutes. Thus, the total data collection time per participant was approximately 30 to 45 minutes. Questionnaire administration and bedside wound scoring were performed by trained nurse investigators, while laboratory values were obtained from the hospital laboratory information system. Nutritional risk was assessed with the MNA-SF, frailty with the GFI, infection severity with IWGDF/IDSA grading, healing risk with SINBAD, and inflammatory biomarkers with CRP, NLR, and CAR derived from routine blood tests.

Bias

Several steps were taken to reduce bias. Selection bias was minimized by using consecutive recruitment of all eligible patients during the study period rather than convenience selection of only easily accessible cases. Information bias was reduced through standardized interviewer-administered questionnaires, use of structured operational definitions, and reliance on same-episode hospital laboratory values rather than patient recall for inflammatory biomarkers and HbA1c. Recall bias for demographic and medical history items was reduced by cross-checking interview responses against the medical record. To improve quality control, the research team used a standardized case-report form, received pre-study training, and reviewed completed forms daily for completeness and internal consistency. Analytic exclusion was limited to participants with missing core exposure or outcome data.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, New York, USA). Continuous variables were summarized as mean and standard deviation when normally distributed or median and interquartile range when skewed, and categorical variables were summarized as frequencies and percentages. Distributional assumptions were assessed using the Shapiro-Wilk test and inspection of histograms. For bivariate analysis, categorical variables were compared using the chi-square test or Fisher exact test, continuous variables across infection-severity groups were compared using one-way analysis of variance or the Kruskal-Wallis test as appropriate, and correlations between ordinal or non-normally distributed variables were assessed using Spearman rank correlation.

Multivariable analyses were prespecified to estimate associations rather than causal effects. Ordinal logistic regression was used for infection severity because the outcome had ordered categories, and binary logistic regression was used for healing risk after dichotomization of SINBAD scores into low risk (<3) and high risk (≥ 3). Adjusted models included age, sex, body mass index, diabetes duration, HbA1c, ulcer duration, and previous ulcer or amputation history as clinically relevant covariates. Because CAR mathematically incorporates CRP, separate adjusted models were fitted for CRP, NLR, and CAR to reduce multicollinearity. Nutritional risk and frailty were entered as categorical variables in the main analysis, and sensitivity analyses repeated the models using their continuous total scores. Cases with missing data in primary exposures, outcomes, or core covariates were excluded by complete-case analysis, and no imputation was performed. All tests were 2-sided, the significance threshold was set at $P < .05$, and effect estimates were reported as odds ratios with 95% confidence intervals

Results

Participant Inclusion and Analytic Sample

Of 110 patients screened during the study period, 19 were excluded, including 8 with non-diabetic foot wounds, 4 with severe communication impairment that precluded questionnaire completion, 5 with incomplete laboratory panels, and 2 with missing infection-severity grading. A total of 91 participants were included in the final analysis, corresponding to a participation rate of 82.7%. All analyses were based on complete-case data. Participant characteristics are shown in Table 1.

Participant Characteristics

The mean (SD) age of the 91 participants was 58.6 (10.9) years, and 57 (62.6%) were male. The median (IQR) duration of diabetes was 12 (7–17) years, 58 participants (63.7%) had hypertension, and the mean (SD) HbA1c level was 9.2% (1.8%). Nutritional risk was present in 67 participants (73.6%), frailty in 38 (41.8%), and a high healing-risk profile in 57 (62.6%). Median (IQR) inflammatory biomarker levels were 18.4 (9.6–34.7) mg/L for CRP, 4.1 (2.9–6.8) for NLR, and 4.7 (2.3–9.1) for CAR. Additional baseline characteristics are presented in Table 1.

Table 1. Participant Characteristics

Characteristic	Overall Sample (N = 91)
Age, mean (SD), y	58.6 (10.9)
Male sex, No. (%)	57 (62.6)
Education, No. (%)	
Primary or junior secondary	31 (34.1)
Senior secondary	42 (46.2)
College or university	18 (19.8)
Occupation, No. (%)	
Employed	29 (31.9)
Unemployed or homemaker	44 (48.4)
Retired	18 (19.8)
Body mass index, mean (SD)	24.7 (4.1)
Diabetes duration, median (IQR), y	12 (7-17)
HbA1c, mean (SD), %	9.2 (1.8)
Hypertension, No. (%)	58 (63.7)
Previous ulcer history, No. (%)	36 (39.6)
Previous amputation history, No. (%)	19 (20.9)
Ulcer duration, median (IQR), wk	6 (3-12)
Nutritional risk (MNA-SF ≤11), No. (%)	67 (73.6)
Frailty (GFI ≥4), No. (%)	38 (41.8)
CRP, median (IQR), mg/L	18.4 (9.6-34.7)
NLR, median (IQR)	4.1 (2.9-6.8)
CAR, median (IQR)	4.7 (2.3-9.1)
High healing risk (SINBAD ≥3), No. (%)	57 (62.6)

Primary Outcome: Infection Severity

Infection severity was graded as mild in 29 participants (31.9%), moderate in 43 (47.3%), and severe in 19 (20.9%). The prevalence of severe infection was 20.9% (95% CI, 13.5%–30.9%). A greater proportion of severe infection was observed among participants with nutritional risk (18 of 67 [26.9%]), frailty (11 of 38 [28.9%]), CRP levels greater than 10 mg/L (16 of 62 [25.8%]), and high healing risk based on the SINBAD score (17 of 57 [29.8%]). The distribution of infection severity across key subgroups is shown in Table 2.

Table 2. Distribution of Infection Severity Overall and by Key Subgroups

Subgroup	Participants, No.	Mild, No. (%)	Moderate, No. (%)	Severe, No. (%)
Overall	91	29 (31.9)	43 (47.3)	19 (20.9)
Nutritional risk: No	24	14 (58.3)	9 (37.5)	1 (4.2)
Nutritional risk: Yes	67	15 (22.4)	34 (50.7)	18 (26.9)
Frailty: No	53	22 (41.5)	23 (43.4)	8 (15.1)
Frailty: Yes	38	7 (18.4)	20 (52.6)	11 (28.9)
CRP ≤10 mg/L	29	17 (58.6)	9 (31.0)	3 (10.3)
CRP >10 mg/L	62	12 (19.4)	34 (54.8)	16 (25.8)
Healing risk: Low (SINBAD <3)	34	20 (58.8)	12 (35.3)	2 (5.9)
Healing risk: High (SINBAD ≥3)	57	9 (15.8)	31 (54.4)	17 (29.8)

Unadjusted Associations With Higher Infection Severity

In unadjusted ordinal logistic regression analyses, nutritional risk was associated with higher odds of greater infection severity (OR, 4.27; 95% CI, 1.51–12.07; P = .006). Frailty (OR, 2.51; 95% CI, 1.12–5.64; P = .03), higher CRP level per 10-mg/L increase (OR, 1.28; 95% CI, 1.09–1.51; P = .003), higher NLR (OR, 1.11; 95% CI, 1.01–1.23; P = .04), and high healing risk (OR, 5.04; 95% CI, 2.00–12.68; P = .001) were also associated with higher infection severity. Age, sex, diabetes duration, hypertension, and previous amputation were not associated with infection severity in the crude analyses. Unadjusted model results are presented in Table 3.

Table 3. Unadjusted Associations Between Participant Characteristics and Higher Infection Severity

Variable	OR	95% CI	P Value
Age, per 10-y increase	1.18	0.86-1.62	.30
Male sex (vs female)	1.31	0.59-2.90	.50
Body mass index, per 1-unit increase	0.96	0.88-1.06	.43
Diabetes duration, per 5-y increase	1.17	0.93-1.47	.18
HbA1c, per 1% increase	1.22	0.99-1.52	.07
Hypertension (yes vs no)	1.45	0.65-3.24	.36
Previous ulcer history (yes vs no)	1.59	0.74-3.40	.23
Previous amputation history (yes vs no)	1.64	0.68-3.94	.27
Ulcer duration >4 wk (vs ≤4 wk)	1.71	0.79-3.69	.17
Nutritional risk (MNA-SF ≤11 vs >11)	4.27	1.51-12.07	.006
Frailty (GFI ≥4 vs <4)	2.51	1.12-5.64	.03
CRP, per 10-mg/L increase	1.28	1.09-1.51	.003
NLR, per 1-unit increase	1.11	1.01-1.23	.04
High healing risk (SINBAD ≥3 vs <3)	5.04	2.00-12.68	.001

Note. Odds ratios were estimated using ordinal logistic regression with infection severity coded as mild, moderate, and severe.

Adjusted Associations With Higher Infection Severity

In the prespecified multivariable ordinal logistic regression model that included CRP, nutritional risk remained associated with higher infection severity (aOR, 3.18; 95% CI, 1.05–9.67; P = .04), as did frailty (aOR, 2.24; 95% CI, 1.01–4.98; P = .048) and higher CRP level per 10-mg/L increase (aOR, 1.22; 95% CI, 1.05–1.42; P = .01). Age, sex, HbA1c, diabetes duration, ulcer duration, previous ulcer history, and previous amputation history were not associated with infection severity after adjustment. Full adjusted estimates are shown in Table 4.

Table 4. Multivariable Associations Between Participant Characteristics and Higher Infection Severity

Variable	aOR	95% CI	P Value
Age, per 10-y increase	1.10	0.78-1.56	.58
Male sex (vs female)	1.22	0.52-2.85	.64
Diabetes duration, per 5-y increase	1.08	0.84-1.38	.55
HbA1c, per 1% increase	1.18	0.94-1.48	.16
Ulcer duration >4 wk (vs ≤4 wk)	1.41	0.61-3.24	.42
Previous ulcer history (yes vs no)	1.36	0.60-3.07	.46
Previous amputation history (yes vs no)	1.37	0.52-3.59	.52
Nutritional risk (MNA-SF ≤11 vs >11)	3.18	1.05-9.67	.04
Frailty (GFI ≥4 vs <4)	2.24	1.01-4.98	.048
CRP, per 10-mg/L increase	1.22	1.05-1.42	.01

Note. Adjusted model included age, sex, diabetes duration, HbA1c, ulcer duration, previous ulcer history, previous amputation history, nutritional risk, frailty, and CRP. ORs were estimated using ordinal logistic regression.

Sensitivity Analyses

Sensitivity analyses yielded findings in the same direction. When CRP was replaced by NLR, higher NLR remained associated with higher infection severity (aOR, 1.10; 95% CI, 1.00–1.22; P = .049). When CRP was replaced by CAR, higher CAR was also associated with higher infection severity (aOR, 1.08; 95% CI, 1.02–1.15; P = .01). Models using continuous MNA-SF and GFI scores showed similar gradients, with lower MNA-SF scores and higher GFI scores associated with higher infection severity.

Discussion.

This study examined the associations of nutritional risk, frailty, and inflammatory biomarkers with infection severity and healing risk in hospitalized patients with diabetic foot ulcers in Ambon, Indonesia. The main finding was that greater host vulnerability and inflammatory burden clustered with more severe diabetic foot infection in this hospital-based sample. In the adjusted model, nutritional risk, frailty, and higher CRP remained associated with higher infection severity, whereas the corresponding associations for NLR and CAR were observed in sensitivity analyses only. To our knowledge, this study adds one of the few integrated datasets from an underrepresented Indonesian wound-care setting that assessed nutritional, functional, and inflammatory domains together in patients with active diabetic foot ulcers. These findings are clinically relevant because diabetic foot ulcers remain common, costly, and prognostically serious in Asian and other resource-constrained settings, where timely risk stratification may improve multidisciplinary care planning (Armstrong et al., 2023; Jeffcoate et al., 2024; Burhan et al., 2025a; Burhan et al., 2025b; Canpolat-Erkan et al., 2026).

The association between nutritional risk and greater infection severity warrants particular consideration. One plausible explanation is that inadequate nutritional reserve may coexist with impaired immune competence, lower protein availability for tissue repair, poorer collagen synthesis, and reduced tolerance of catabolic stress during active infection, all of which are relevant in chronic wound states (Lauwers et al., 2022; Ran et al., 2024). A second explanation is that frailty may capture a broader syndrome of reduced physiologic reserve, sarcopenia, decreased mobility, and diminished self-management capacity, which could complicate pressure relief, foot care, and timely presentation for treatment in people with diabetic foot disease (Bilici & Kılıç, 2026; Jiao et al., 2025; Neal et al., 2026). These pathways are especially plausible in hospitalized patients with diabetic foot ulcers because they commonly present with multimorbidity, long diabetes duration, recurrent ulceration, and a high burden of vascular and inflammatory abnormalities (Jeffcoate et al., 2024; Armstrong et al., 2023). However, these explanations remain inferential, and the cross-sectional design does not establish temporality or causation.

Overall, these findings are generally consistent with previous literature, although the specific pattern of associations varied across studies. Prior reviews and hospital-based studies have suggested that malnutrition is common in diabetic foot ulcer populations and is associated with ulcer severity, prolonged hospitalization, and poorer outcomes, while frailty has been linked to diabetic foot ulcer risk, mortality, and impaired foot self-care behavior (Lauwers et al., 2022; Ran et al., 2024; Jiao et al., 2025; Neal et al., 2026; Bilici & Kılıç, 2026). The biomarker findings are also aligned with evidence that CRP, and to a lesser extent NLR or CAR, may support diabetic foot infection stratification, with a recent study by Canpolat-Erkan et al. (2026) and a meta-analysis by Wang et al. (2023) highlighting the value of inflammatory markers in infected diabetic foot assessment (Canpolat-Erkan et al., 2026; Wang et al., 2023). In contrast, several wound-care studies in the uploaded wound-care table mainly examined local wound management strategies, such as advanced dressings, topical antimicrobials, NPWT, regional prevalence patterns, and TcPO2 monitoring, rather than integrated host-level correlates of infection severity, which limits direct comparison with the present analysis (Burhan et al., 2022; Burhan et al., 2025b; Burhan et al., 2025c; Haruka et al., 2025; Romano et al., 2025; Srisawat et al., 2025). Differences in outcome definitions, severity mix, biomarker timing, wound-care context, and covariate adjustment may explain both the agreements and the differences across studies. This study therefore extends prior work by adding data from an Indonesian hospital-based diabetic foot population using concurrent nutritional, frailty, and inflammatory measurements.

This study has several strengths. It assessed multiple host-related domains that are often studied separately, used clinically relevant infection grading, and was conducted in a real-world hospital setting where the burden of diabetic foot disease is substantial. The main limitation is that the cross-sectional design precludes establishing temporal sequence or causal inference between nutritional risk, frailty, inflammatory biomarkers, and infection severity. Additional limitations include the single-center setting, modest sample size, use of some interview-based measures, and the possibility of residual confounding from unmeasured vascular, microbiological, or treatment-related factors. Exclusion of some patients with incomplete laboratory or assessment data may have reduced representation of the sickest or most complex cases and may have biased some estimates toward the null. Accordingly, the findings should be generalized cautiously, primarily to similar hospital-based diabetic foot ulcer populations in Indonesia or comparable resource-constrained settings in Asia.

The main implication of this study is that bedside assessment of diabetic foot ulcers may benefit from going beyond local wound inspection alone to include structured nutritional screening, frailty assessment, and routine inflammatory markers. Hospitals and wound-care teams should consider whether multidisciplinary pathways that combine wound nursing, infection assessment, nutritional support, and functional screening may improve early risk identification in patients with diabetic foot ulcers. This study adds value by complementing the intervention-oriented wound-care literature from the uploaded table, which has emphasized dressings, topical therapies, NPWT, and wound monitoring, with patient-level data on host vulnerability in an Indonesian hospital context (Burhan et al., 2022; Burhan et al., 2025a; Burhan et al., 2025c; Haruka et al., 2025; Romano et al., 2025; Srisawat et al., 2025). Future studies should use multicenter longitudinal designs and interventional approaches to determine whether modifying nutritional, frailty, or inflammatory profiles is associated with changes in infection severity, healing trajectories, or limb outcomes over time. In summary, among hospitalized patients with diabetic foot ulcers, nutritional risk, frailty, and CRP were associated with greater infection severity, supporting a broader host-centered approach to diabetic foot risk assessment.

Strengths And Limitations of The Study

This study has important strengths, including the use of clinically relevant wound outcomes, the concurrent assessment of nutritional risk, frailty, and inflammatory biomarkers, and the conduct of data collection in a real-world hospital setting where diabetic foot ulcers are commonly managed. At the same time, the cross-sectional design does not allow conclusions about temporality or causal direction between host-related factors and infection severity or healing risk. Some measurements, particularly nutritional and frailty assessments, relied in part on interviewer-administered instruments and medical record verification, which may have introduced reporting error or modest classification imprecision. Selection bias also remains possible because the study was conducted at a single hospital and included only patients with complete assessment and laboratory data, which may have limited representativeness and may have attenuated or inflated some observed associations. Residual confounding cannot be excluded, particularly for unmeasured factors such as vascular status, microbiological burden, prior treatment exposure, and detailed wound-care practices. These considerations do not negate the clinical relevance of the findings, but they do indicate that the results should be interpreted cautiously and generalized primarily to comparable hospital-based diabetic foot ulcer populations.

Implications For Nursing Practice

These findings suggest that nursing practice may benefit from a broader bedside assessment approach that considers not only local wound characteristics but also nutritional risk, frailty status, and inflammatory burden in patients with diabetic foot ulcers. Nurses should be attentive to early signs of poor nutritional reserve, reduced functional resilience, and elevated inflammatory activity because these factors were associated with greater infection severity and may help identify patients who require closer monitoring and more coordinated care. At the organizational level, nursing leadership and educators may consider integrating structured nutritional screening, frailty assessment, and biomarker review into wound-care workflows, competency training, and multidisciplinary communication pathways. Such an approach may support earlier risk recognition, more individualized care planning, and better alignment between wound management, supportive care, and discharge preparation. Although these findings do not establish causation, they may help guide targeted nursing strategies while longer-term multicenter studies clarify how these assessments relate to subsequent healing and limb outcomes

Conclusions

Among hospitalized patients with diabetic foot ulcers, greater nutritional risk, frailty, and higher inflammatory burden were associated with more severe infection at the time of assessment. The findings highlight the clinical relevance of combining host-related screening with routine wound evaluation, rather than relying on local ulcer features alone. A more integrated nursing assessment model may therefore be useful in diabetic foot care, although longitudinal studies are still needed to clarify temporality and support future practice recommendations

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Conflict of Interest Statement
The authors declare that they have no competing interests.

Author contribution
Samsul Adipati conceptualized the study, coordinated data collection, and drafted the initial manuscript. Faruk Akbar contributed to study implementation, data curation, and manuscript preparation. Asmat Burhan provided supervision, and critical review of the manuscript draft. All authors read and approved the final version of the manuscript.

Data Avaibility
The data that support the findings of this study are available from the corresponding author upon reasonable request

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