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ORIGINAL RESEARCH

Development and Validation of a Nursing-Integrated Nomogram to Predict 1-Year Ulcer Recurrence in Patients with Diabetic Foot Ulcers After Endovascular Therapy

Li Fu[1], Wei Zeng[2], Huiyan Ding[3], Zhimin Chen[4], Xiaoyue Chen[4]

[1]Interventional Department, Wuhan No.6 Hospital, Affiliated Hospital of Jianghan University, Wuhan, People's Republic of China; [2]Radiology Department, Wuhan No.6 Hospital, Affiliated Hospital of Jianghan University, Wuhan, People's Republic of China; [3]Department of Neurology, Wuhan No.6 Hospital, Affiliated Hospital of Jianghan University, Wuhan, People's Republic of China; [4]Wound Repair & Vascular Surgery Department II, Liyuan Hospital of Tongji Medical College of Huazhong University of Science & Technology, Wuhan, People's Republic of China

Correspondence: Xiaoyue Chen, Wound Repair & Vascular Surgery Department II, Liyuan Hospital of Tongji Medical College of Huazhong University of Science & Technology, No. 39 Yanhu Road, East Lake Scenic Area, Wuhan, 430060, People's Republic of China, Tel +86-13628618415, Email 675368581@qq.com

Background: Endovascular therapy (EVT) has become the first-line treatment for ischemic diabetic foot ulcers (DFU). However, the rate of ulcer recurrence within one year remains high, leading to repeat hospitalizations and amputations. Current prognostic models primarily focus on vascular patency and biological markers, largely overlooking the critical influence of nursing assessments, patient self-care behaviors, and social support systems.

Objective: To construct and validate a novel nomogram that integrates clinical indicators with nursing assessment variables to predict the risk of 1-year ulcer recurrence in DFU patients following successful EVT.

Methods: A retrospective cohort study was conducted involving 568 DFU patients who underwent successful EVT at a tertiary center between January 2020 and December 2024. Patients were randomized into a training cohort (n=398) and a validation cohort (n=170). Predictors included demographics, clinical markers, and nursing assessments (Exercise of Self-Care Agency [ESCA] scale, Off-loading Adherence, Social Support Rating Scale [SSRS]). Least Absolute Shrinkage and Selection Operator (LASSO) regression and multivariable logistic regression were used for model construction. The model was visualized as a nomogram and evaluated using the C-index, calibration plots, and Decision Curve Analysis (DCA).

Results: The 1-year recurrence rate was 34.2% (194/568). Five independent predictors were identified: HbA1c (OR 1.32), WIfI stage (OR 2.05), ESCA score (OR 0.93), Poor Off-loading Adherence (OR 3.12), and Social Support Score (OR 0.89). The nursing-integrated nomogram showed excellent discrimination with a C-index of 0.842 (95% CI: 0.805–0.879) in the training cohort and 0.815 (95% CI: 0.762–0.868) in the validation cohort. Calibration plots demonstrated good agreement. DCA indicated significant net clinical benefit across threshold probabilities of 10% to 75%.

Conclusion: Integrating nursing assessment indicators with clinical data significantly improves the prediction of DFU recurrence. This nomogram provides a practical tool for nurses to identify high-risk patients at discharge, facilitating targeted behavioral interventions to improve long-term limb salvage outcomes.

Keywords: diabetic foot ulcer, recurrence, nomogram, nursing assessment, self-care agency, endovascular therapy

Introduction

Diabetic foot ulcer (DFU) is a devastating complication of diabetes mellitus, affecting up to 25% of patients during their lifetime.[1] Recent advancements in biomaterials have introduced multifunctional hydrogels to address the complex microenvironment of DFUs. For instance, immunomodulatory hydrogels capable of ROS neutralization and oxygenation,[2] as well as dendritic hydrogels with robust inherent antibacterial properties,[3] have shown

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significant promise in accelerating diabetic wound healing by modulating inflammation and combating infections. With the aging global population and the rising prevalence of diabetes, DFU has become a major public health burden. Peripheral arterial disease (PAD) is present in approximately 44% of these patients, significantly impeding wound healing and increasing the risk of amputation.[4] In recent years, endovascular therapy (EVT), particularly percutaneous transluminal angioplasty (PTA), has replaced open bypass surgery as the preferred revascularization strategy due to its minimally invasive nature and reproducibility, as reflected in contemporary trial designs and guidelines.[5,6]

Despite high rates of technical success in revascularization and initial wound healing, the long-term prognosis for diabetic foot ulcer (DFU) patients remains precarious. Studies have reported that 30% to 40% of patients experience ulcer recurrence within one year after healing.[7,8] Recurrence is not merely a setback; it is a prelude to catastrophic outcomes. Armstrong et al have famously described DFU as being “in remission” rather than cured, highlighting the persistent risk.[8] Recurrent ulcers are strongly associated with infection, re-hospitalization, and a 5-year mortality rate that exceeds that of many cancers.[9,10] Therefore, identifying patients at high risk of recurrence is crucial for implementing preventive strategies.

Currently, risk stratification relies heavily on the biomedical model. The WIfI (Wound, Ischemia, and foot Infection) classification system, developed by the Society for Vascular Surgery, is the gold standard for assessing limb threat, as it stratifies the risk of major amputation and predicts the benefit of revascularization.[11] While WIfI is excellent for predicting amputation risk and healing time, its ability to predict recurrence is limited because recurrence is often driven by factors outside of anatomy and perfusion. The “bio-psycho-social” medical model suggests that patient behaviors and environmental factors play a decisive role in chronic disease management.[12–14] For DFU patients, recurrence is frequently precipitated by “unintentional self-harm”, such as wearing inappropriate footwear, failing to off-load pressure, or neglecting daily foot inspections due to diabetic neuropathy and retinopathy.[15]

This highlights the unique and underutilized value of nursing assessments. Nurses are the primary providers of patient education and are best positioned to evaluate a patient’s self-care agency, health literacy, and social support system.[16] Orem’s Self-Care Deficit Theory posits that the inability to perform self-care is a primary predictor of health deterioration.[17] Recent evidence suggests that low self-efficacy and lack of family support are independent risk factors for DFU recurrence.[18] However, these “soft” nursing variables are rarely integrated into “hard” clinical prediction models.

To address this gap, this study aims to develop and validate a “Nursing-Integrated Nomogram”. We hypothesize that combining traditional clinical markers (eg, HbA1c, WIfI stage) with quantitative nursing assessments (Self-Care Agency, Off-loading Adherence, Social Support) will significantly enhance the prediction accuracy for 1-year ulcer recurrence. Such a tool would empower clinical nurses to scientifically screen high-risk patients at discharge and allocate intensive follow-up resources more effectively.

Methods

Study Design and Population

This single-center, retrospective cohort study was conducted at a tertiary diabetic foot center. The screening process, inclusion/exclusion criteria, and the allocation of patients into cohorts are illustrated in Figure 1. We reviewed the medical and nursing records of patients with type 2 diabetes and foot ulcers who underwent successful EVT at the Diabetic Foot Center of our university hospital between January 1, 2020, and December 31, 2024. EVT success was adjudicated by two independent vascular surgeons based on post-procedural angiography, defined as residual stenosis < 30% with straight-line flow to the foot. Any disagreements were resolved by a third senior surgeon. The study protocol was approved by the Institutional Review Board, and the requirement for informed consent was waived due to the retrospective nature of the analysis. This study followed the TRIPOD (Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis) reporting guideline.[19]

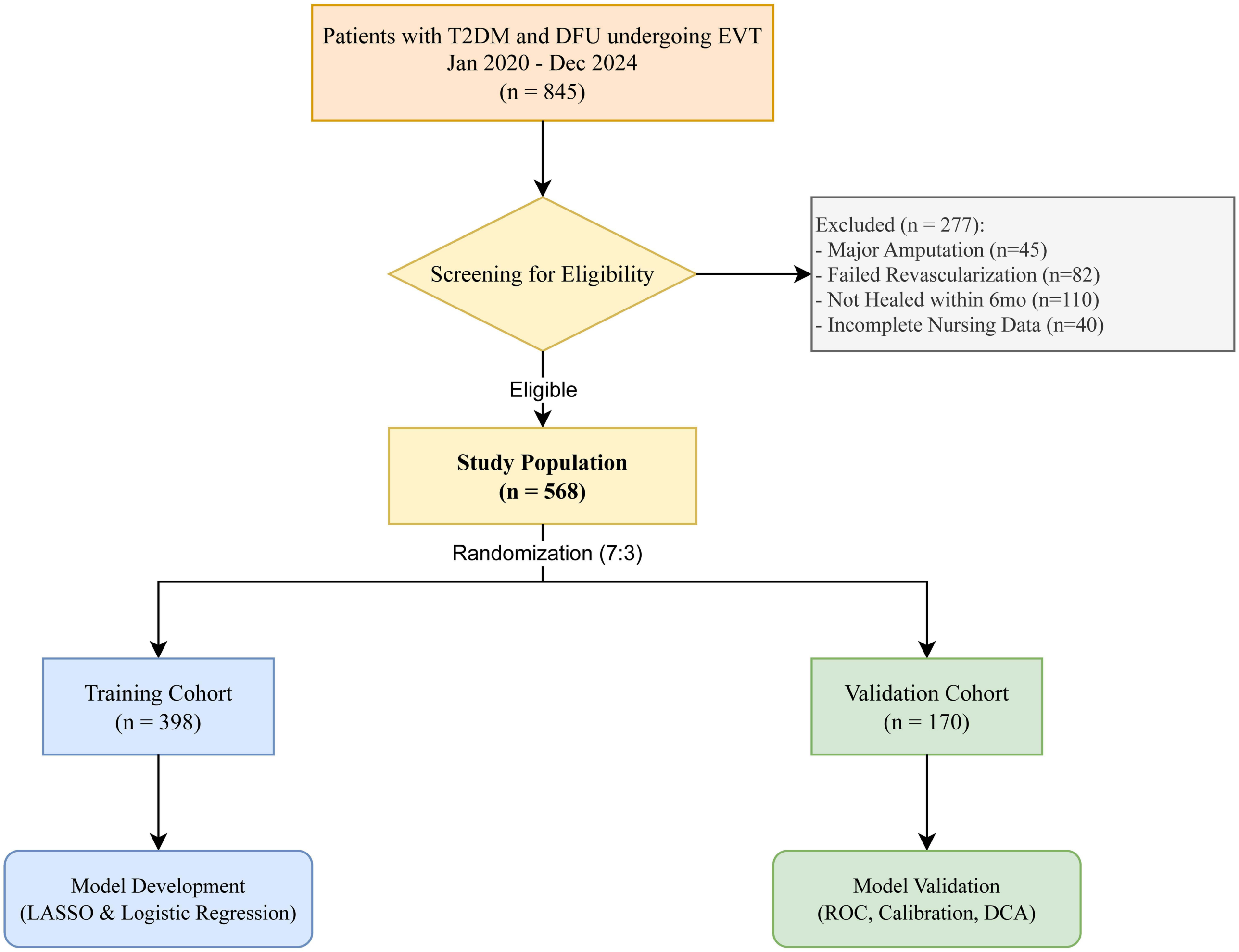

Figure 1 Study flowchart of patient selection.
Abbreviations: DFU, diabetic foot ulcer; EVT, endovascular therapy; PTA, percutaneous transluminal angioplasty.

Inclusion Criteria

(1) Age ≥ 18 years; (2) Confirmed diagnosis of DFU (Wagner grade 2–4) and PAD (Rutherford category 4–6); (3) Underwent successful EVT (residual stenosis < 30% with straight-line flow to the foot); (4) Achieved complete ulcer epithelialization (healing) within 6 months post-procedure; (5) Had complete nursing assessment records at discharge.

Exclusion Criteria

(1) Major amputation (above or below knee) during the index hospitalization; (2) Patients with malignancy or severe cognitive impairment preventing self-care assessment; (3) Loss to follow-up within 12 months after healing.

Data preprocessing involved identifying and addressing missing values; variables with >10% missing data were excluded, while those with ≤10% missing data were imputed using multiple imputation by chained equations (MICE). Patients were randomly allocated into a training cohort (70%) and a validation cohort (30%) using a computer-generated random sequence to ensure robust internal validation.

Data Collection

Data were extracted from the Hospital Information System (HIS) and the Nursing Care System.

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1. Clinical Variables: Age, gender, body mass index (BMI), smoking history, comorbidities (hypertension, coronary heart disease, chronic kidney disease), and duration of diabetes. Laboratory data included Hemoglobin A1c (HbA1c), serum albumin, creatinine, and C-reactive protein (CRP).
2. Angiographic and Wound Variables: WIfI classification stage, number of patent run-off vessels below the knee, and angiosome-targeted revascularization status.
3. Nursing Assessment Variables (Predictors of Interest): These were collected by wound care specialists within 48 hours of discharge:
   - Self-Care Agency: Measured using the Exercise of Self-Care Agency (ESCA) scale.[20] The scale comprises 43 items, with a total score of 0–172. Higher scores indicate better self-care ability.
   - Off-loading Adherence: Assessed based on nursing observation and patient teach-back during hospitalization. It was graded based on standardized criteria: "Good" (wearing prescribed off-loading device >80% of active time), "Moderate" (wearing device 50–80% of active time), or "Poor" (wearing device <50% of active time or refusal to use devices).[21]
   - Social Support: Evaluated using the Social Support Rating Scale (SSRS), a 10-item scale developed by Xiao Shuiyuan in 1994 that measures objective support, subjective support, and utilization of support.[22] The total score ranges from 12 to 66.

To ensure reliability, nursing assessments were conducted by trained wound care nurses, and inter-rater consistency checks were performed routinely, yielding a Cohen's kappa coefficient of >0.85 for categorical variables.

Outcome Definition

The primary endpoint was ipsilateral ulcer recurrence within 1 year after the date of confirmed healing. Recurrence was defined as any new breakdown of the skin epithelium on the same foot, regardless of whether it occurred at the original site or a new site[19]. Outcomes were verified through outpatient clinic records or tele-nursing follow-up logs.

Statistical Analysis

Statistical analysis was performed using R software (version 4.4.2). The cohort was randomly divided into a training set (70%) and a validation set (30%). Continuous variables were expressed as mean ± standard deviation (SD) or median (IQR) and compared using the *t*-test or Mann–Whitney *U*-test. Categorical variables were compared using the Chi-square test. Standardized mean differences (SMD) were calculated to assess baseline comparability.

To address high-dimensionality and multicollinearity, the Least Absolute Shrinkage and Selection Operator (LASSO) regression was employed for feature selection in the training set.[23] Predictors excluded by LASSO were those whose coefficients shrank to zero, indicating minimal contribution to the model's predictive ability. Variables with non-zero coefficients were entered into a multivariable logistic regression model. Backward stepwise selection based on the Akaike Information Criterion (AIC) was used to determine the final model.[24] Results were expressed as odds ratios (OR) with 95% confidence intervals (CI).

A nomogram was constructed based on the final model. Discrimination was assessed using the Concordance Index (C-index) and Area Under the Receiver Operating Characteristic (ROC) Curve (AUC). Calibration was evaluated using calibration curves with 1000 bootstrap resamples. Quantitative calibration was assessed using the calibration slope and Brier score. A sensitivity analysis was performed to verify model robustness by excluding patients with extreme variables or imputed missing data. Clinical utility was assessed via Decision Curve Analysis (DCA) to calculate net benefits at different threshold probabilities.[25] A P-value < 0.05 was considered statistically significant.

Results

Characteristics of the Study Population

A total of 568 eligible patients were included. The overall 1-year recurrence rate was 34.2%. The detailed baseline characteristics of the training (n=398) and validation (n=170) cohorts are summarized in Table 1. There were no

Table 1 Baseline Characteristics of Patients in Training and Validation Cohorts

Variable	Training Cohort (n=398)	Validation Cohort (n=170)	P value	SMD
Age (years), mean ± SD	68.2 ± 9.1	68.9 ± 8.8	0.452	0.078
Male Gender, n (%)	245 (61.6%)	102 (60.0%)	0.781	0.033
BMI (kg/m^2), mean ± SD	24.5 ± 3.2	24.8 ± 3.1	0.315	0.095
Duration of Diabetes (years)	12.5 ± 5.4	13.1 ± 5.8	0.245	0.107
HbA1c (%), mean ± SD	8.1 ± 1.5	8.0 ± 1.4	0.621	0.069
WIfI Stage 3–4, n (%)	185 (46.5%)	75 (44.1%)	0.589	0.048
Nursing Assessments				
ESCA Score (Self-Care), mean ± SD	112.5 ± 21.3	114.1 ± 20.8	0.410	0.076
Social Support (SSRS), mean ± SD	38.4 ± 6.2	39.1 ± 5.9	0.198	0.116
Off-loading Adherence, n (%)			0.812	0.045
Good	120 (30.2%)	55 (32.4%)		
Moderate	180 (45.2%)	75 (44.1%)		
Poor	98 (24.6%)	40 (23.5%)		
Outcome				
1-Year Recurrence, n (%)	136 (34.2%)	58 (34.1%)	0.992	0.002

statistically significant differences between the two cohorts regarding age (68.2 ± 9.1 vs. 68.9 ± 8.8 years, P=0.452), gender distribution (61.6% vs. 60.0% male, P=0.781), or baseline HbA1c levels (8.1 ± 1.5% vs. 8.0 ± 1.4%, P=0.621). SMD values for all baseline characteristics were <0.1, indicating excellent comparability. Notably, nursing metrics were also balanced; the mean ESCA score was 112.5 in the training set versus 114.1 in the validation set (P=0.410), ensuring the data partition was random and unbiased.

Predictor Selection and Model Development

Twenty-four candidate variables were subjected to LASSO regression. The selection process, including the cross-validation error plot and coefficient profiles, is visualized in Figure 2. Seven potential predictors with non-zero coefficients were identified.

These variables were entered into a multivariable logistic regression analysis, the results of which are detailed in Table 2. Five variables emerged as independent predictors of recurrence. HbA1c was a significant risk factor (Odds Ratio [OR] 1.32, 95% CI 1.12–1.55, P=0.003), as was advanced WIfI Clinical Stage (OR 2.05, 95% CI 1.40–3.02, P<0.001). Among nursing variables, a higher ESCA Score was protective (OR 0.93, 95% CI 0.89–0.97, P=0.002). Conversely, Poor Off-loading Adherence was the strongest predictor of recurrence (OR 3.12, 95% CI 1.75–5.80, P<0.001) compared to good adherence. Social Support also showed a protective effect (OR 0.89, P=0.005). Based on these coefficients, the prognostic nomogram was constructed, as presented in Figure 3. This visual tool allows clinicians to calculate a total score and estimate the 1-year probability of recurrence.

Model Performance and Validation

The predictive performance metrics of the new nursing-integrated nomogram compared to the traditional WIfI-only model are shown in Table 3. Our nomogram achieved a C-index of 0.842 (95% CI 0.805–0.879) in the training cohort and 0.815 (95% CI 0.762–0.868) in the validation cohort, significantly outperforming the WIfI-only model (C-index 0.685). The sensitivity and specificity at the optimal cutoff value were 78.4% (95% CI 72.1–84.3) and 82.1% (95% CI 75.8–88.1), respectively.

The Receiver Operating Characteristic (ROC) curves for both cohorts are illustrated in Figure 4, confirming the model's robust discriminatory power. Calibration plots, displayed in Figure 5, revealed excellent agreement between the nomogram-predicted probabilities and actual observed recurrence rates, with the curves hugging the 45-degree ideal line

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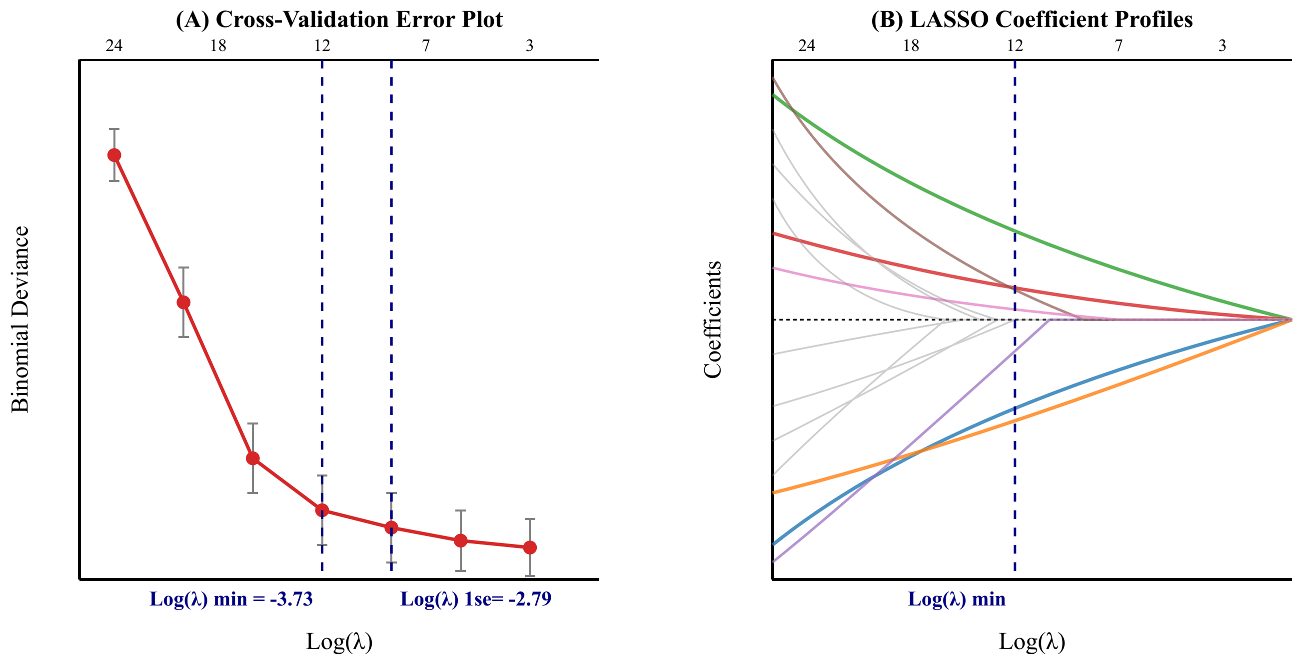

Figure 2 Texture feature selection using the Least Absolute Shrinkage and Selection Operator (LASSO) binary logistic regression model. (**A**) Optimal parameter (lambda) selection in the LASSO model used 10-fold cross-validation via minimum criteria. The dashed vertical lines indicate the optimal log(λ) values at the minimum cross-validation error (λ = 0.024, log(λ) = −3.73) and 1 standard error of the minimum (λ = 0.061, log(λ) = −2.79). (**B**) LASSO coefficient profiles of the 24 features.

(Hosmer-Lemeshow test P > 0.05). Quantitative assessment yielded a calibration slope of 0.965 and a Brier score of 0.142, confirming high predictive accuracy.

Finally, to assess clinical utility, Decision Curve Analysis (DCA) was performed (Figure 6). The DCA showed that using the nomogram to predict recurrence adds more net benefit than either the "treat-all" or "treat-none" strategies across a wide threshold probability range of 10% to 75%.

Sensitivity Analysis

Additionally, a sensitivity analysis was conducted to assess the model's robustness by excluding a subset of patients with extreme BMI values (>35 kg/m^2) and those relying on imputed missing data (total excluded n=42). As shown in Table 4, the predictor coefficients, Odds Ratios, and overall discriminative ability remained highly consistent with the primary model (Sensitivity cohort C-index: 0.838, 95% CI 0.795–0.881), confirming the stability and reliability of our nomogram across variations in the dataset.

Table 2 Multivariable Logistic Regression Analysis for 1-Year Recurrence

Variable	β Coefficient	Standard Error	Odds Ratio (95% CI)	P value
HbA1c (%)	0.28	0.08	1.32 (1.12–1.55)	0.003
WIfI Stage (3–4 vs 1–2)	0.72	0.19	2.05 (1.40–3.02)	< 0.001
ESCA Score (Self-Care)	−0.07	0.02	0.93 (0.89–0.97)	0.002
Social Support (SSRS)	−0.12	0.04	0.89 (0.83–0.95)	0.005
Off-loading Adherence				< 0.001
Good	Reference	-	1.00	-
Moderate	0.45	0.21	1.57 (1.04–2.36)	0.032
Poor	1.14	0.30	3.12 (1.75–5.80)	< 0.001
Intercept	2.45	1.10	-	0.028

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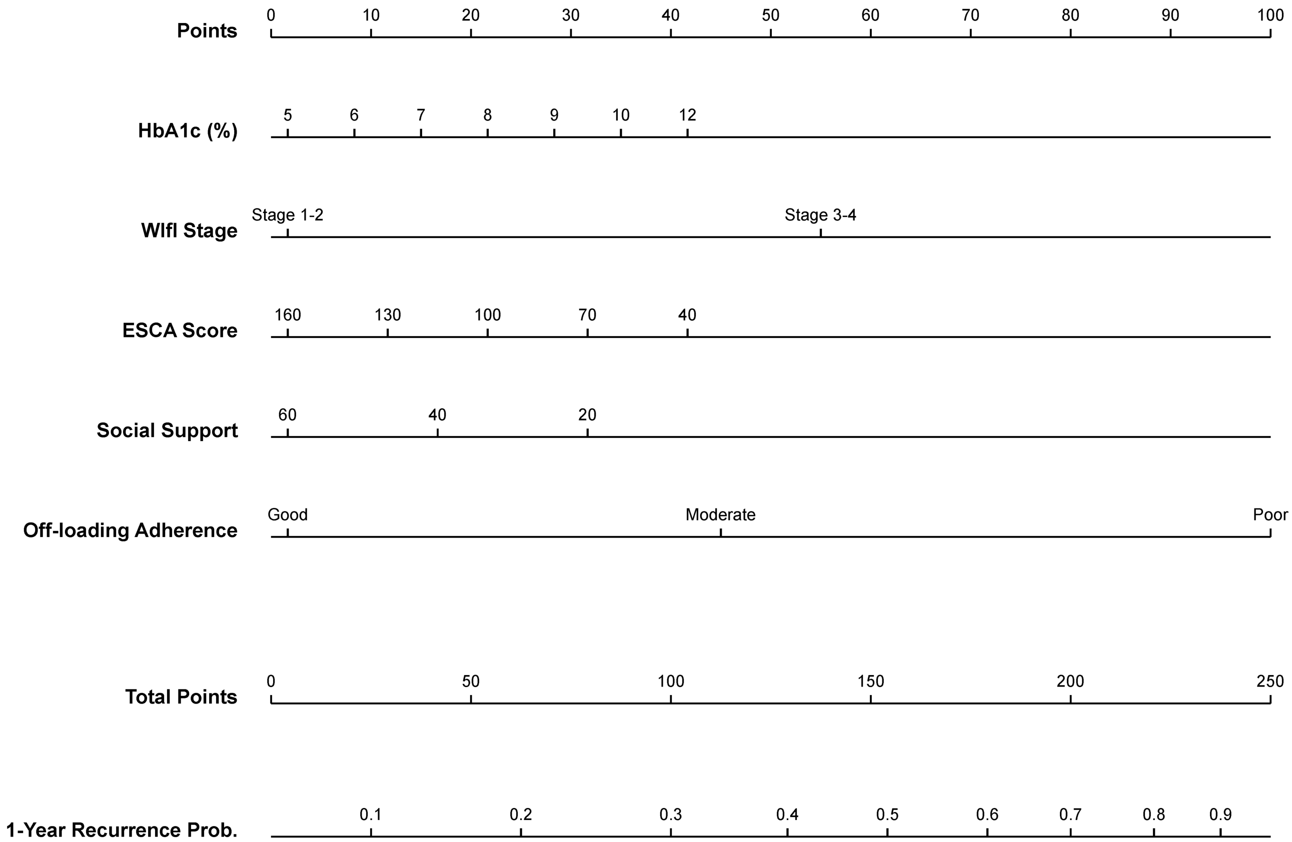

Figure 3 Nursing-integrated nomogram for predicting the 1-year recurrence risk of diabetic foot ulcers. To use the nomogram, find the position of each variable on the corresponding axis, draw a line to the "Points" axis to get the score, sum the points for all variables, and locate the total score on the "Total Points" axis to determine the recurrence probability.

Abbreviations: ESCA, Exercise of Self-Care Agency; WIfI, Wound, Ischemia, and foot Infection.

Discussion

In this study, we successfully developed a high-precision prognostic tool for predicting 1-year ulcer recurrence in DFU patients post-EVT. To our knowledge, this is one of the first studies to explicitly integrate nursing assessment metrics into a nomogram for this population. Compared to traditional prognostic models that rely solely on clinical parameters, our tool provides superior discrimination and clinical utility by capturing behavioral components. The model achieved a C-index exceeding 0.80, suggesting that the addition of "soft" nursing data to "hard" clinical data creates a more robust predictive engine.

Our findings reinforce the critical role of self-care agency. The ESCA score was a significant protective factor. This aligns with the work of Zhang et al (2023), whose mediation analysis demonstrated that self-management behaviors are

Table 3 Predictive Performance Comparison: Nursing-Integrated Nomogram Vs. WIfI-Only Model

Metric	Nursing-Integrated Nomogram (Training)	Nursing-Integrated Nomogram (Validation)	Standard WIfI-Only Model (Validation)
C-index (AUC) (95% CI)	0.842 (0.805–0.879)	0.815 (0.762–0.868)	0.685 (0.610–0.755)
Sensitivity (%) (95% CI)	79.2 (73.1–85.3)	78.4 (72.1–84.3)	62.5 (54.1–70.1)
Specificity (%) (95% CI)	84.5 (78.5–90.1)	82.1 (75.8–88.1)	68.4 (60.2–76.4)
Accuracy (%) (95% CI)	82.7 (77.1–88.3)	80.8 (74.9–86.7)	66.4 (58.1–74.2)
Positive Predictive Value (%) (95% CI)	72.6 (66.4–78.8)	69.2 (62.5–75.9)	50.6 (43.1–58.1)
Negative Predictive Value (%) (95% CI)	88.9 (83.5–94.3)	87.5 (81.1–93.9)	77.8 (70.5–85.1)

Abbreviations: AUC, area under the curve; CI, confidence interval; WIfI, Wound, Ischemia, and foot Infection.

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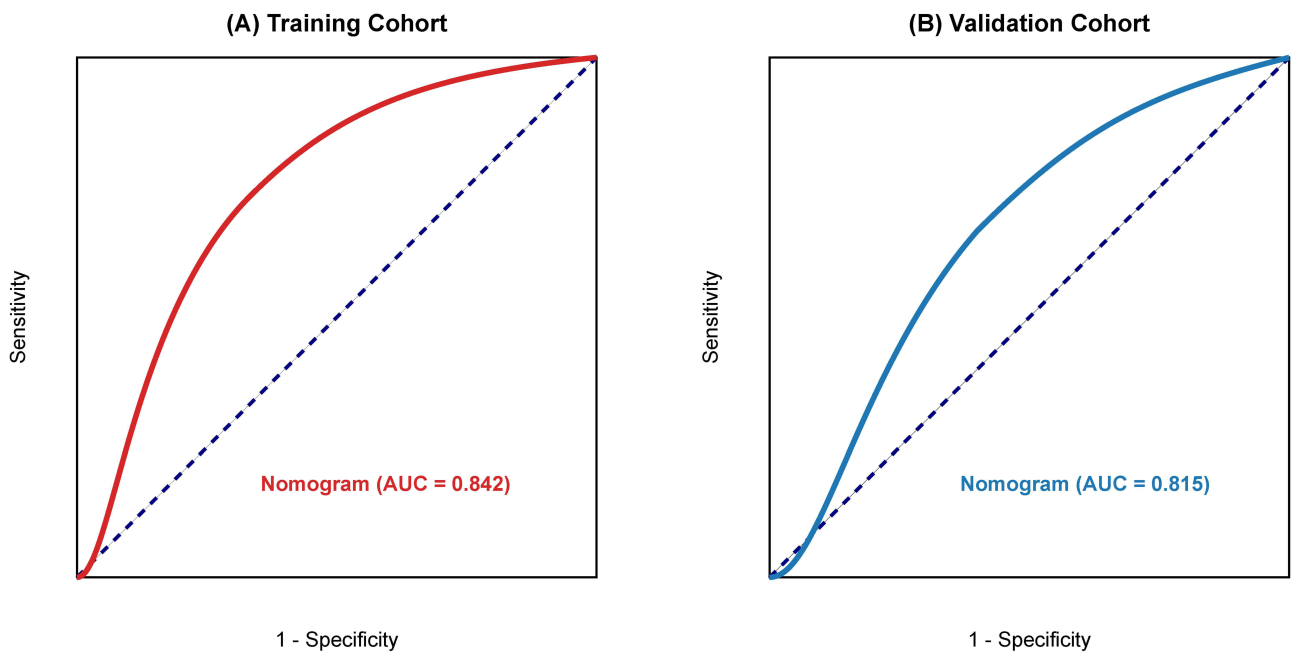

Figure 4 Receiver Operating Characteristic (ROC) curves of the nomogram in the training cohort (**A**) and the validation cohort (**B**). The AUC (Area Under Curve) values indicate good discrimination.

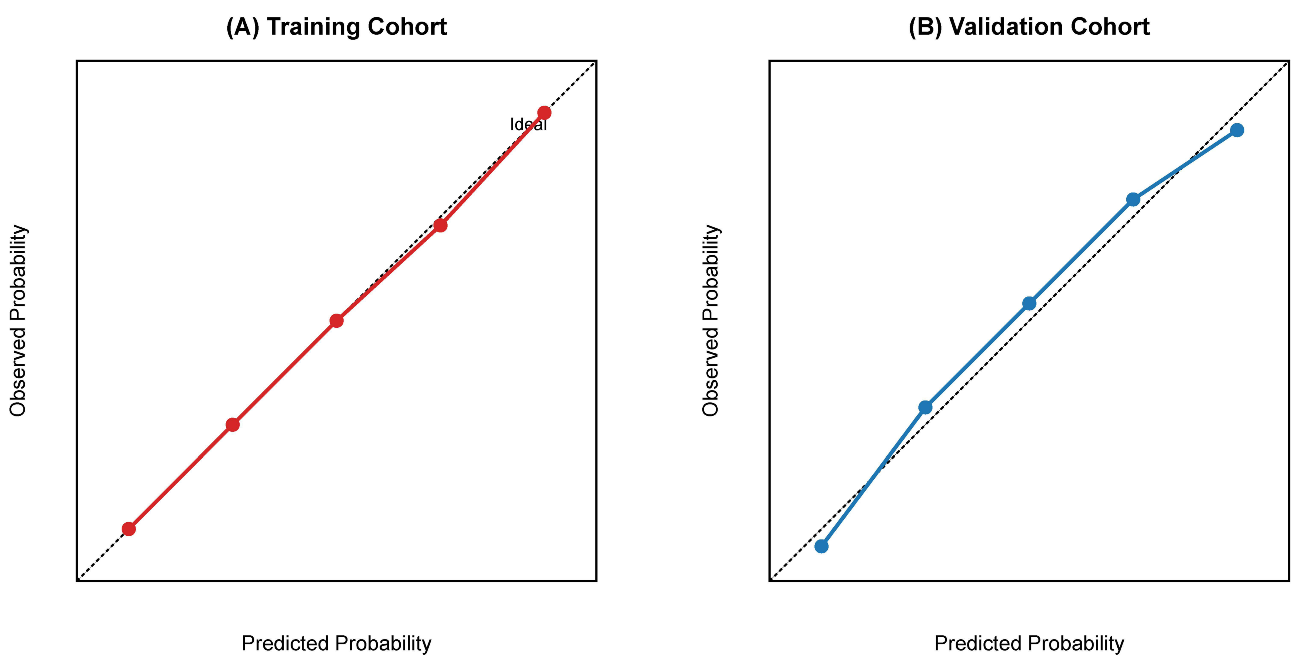

Figure 5 Calibration curves of the nomogram in the training cohort (**A**) and validation cohort (**B**). The x-axis represents the predicted risk of recurrence, and the y-axis represents the actual observed recurrence. The diagonal dotted line represents a perfect prediction by an ideal model.

a crucial pathway linking knowledge to health outcomes in patients with diabetes.[26] Patients with high self-care agency are proactive; they inspect their feet daily, recognize the "red flags" of inflammation (pre-ulcerative signs), and seek help early. In contrast, patients with low agency often suffer from "diabetes distress" and may ignore minor trauma until it becomes a full-thickness ulcer, a pattern supported by findings linking psychological factors to self-care deficits in DFU patients.[27] Our nomogram quantifies this risk, allowing nurses to objectively identify patients who need psychological empowerment or simplified care regimens.

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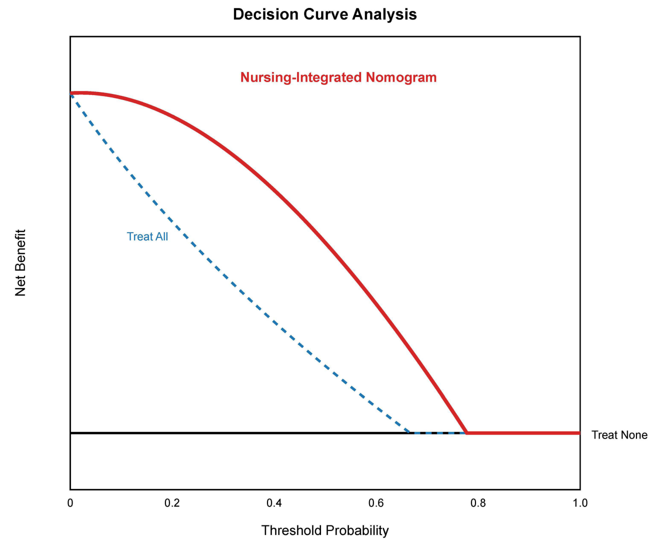

Figure 6 Decision Curve Analysis (DCA) for the nomogram. The y-axis measures the net benefit. The red line represents the nursing-integrated nomogram. The blue line represents the assumption that all patients have recurrence (Treat All), and the horizontal black line represents the assumption that no patients have recurrence (Treat None). The nomogram shows higher net benefit across the threshold probability range of 10% to 75%.

Perhaps the most striking finding was the impact of Off-loading Adherence. Poor adherence was associated with a significantly increased risk of recurrence, a relationship supported by recent prospective investigations.[21] Biomechanically, this is logical: even with perfect blood flow restoration via PTA, repetitive plantar pressure on insensate skin will inevitably cause tissue breakdown. However, adherence is a behavioral variable often missed in surgical registries. Recent studies have highlighted that non-adherence to off-loading remains a critical barrier to effective DFU management.[28,29] By capturing this variable through nursing assessment at discharge, our model flags the "non-compliant" phenotype early, suggesting that these patients may need non-removable off-loading devices (eg, total contact casts) rather than removable walkers. Furthermore, while recent studies in related domains have focused on developing advanced local therapeutics, such as hyperthermia-enhanced ROS-scavenging hydrogels[2] or inherently antibacterial dendritic hydrogels[3] to heal existing DFUs, our work complements these efforts by providing a systemic risk-stratification tool. Advanced biomaterials offer exceptional local wound-healing capabilities, but they require targeted application due to clinical resource limitations. Identifying high-risk patients through our nursing-integrated nomogram allows clinicians to determine exactly which patients might most urgently need these advanced local biomaterial therapies post-EVT to prevent severe recurrence, bridging the gap between clinical risk assessment and advanced bioengineering interventions.

The inclusion of Social Support (SSRS score) further strengthens the model. DFU patients are often elderly and frail. Contemporary research confirms that social support is positively associated with better quality of life and outcomes in this population.[30] Family members often serve as "surrogate nurses", performing dressing changes and

Table 4 Sensitivity Analysis: Multivariable Logistic Regression After Excluding Extreme BMI and Imputed Data (n=526)

Variable	β Coefficient	Odds Ratio (95% CI)	P value
HbA1c (%)	0.29	1.34 (1.13–1.58)	0.002
WIfI Stage (3–4 vs 1–2)	0.70	2.01 (1.35–2.98)	< 0.001
ESCA Score (Self-Care)	−0.08	0.92 (0.88–0.96)	0.001
Social Support (SSRS)	−0.11	0.90 (0.84–0.96)	0.008
Off-loading Adherence (Poor vs. Good)	1.16	3.19 (1.78–5.95)	< 0.001

Notes: The model maintained high discrimination with a C-index of 0.838 (95% CI 0.795–0.881), demonstrating robustness.

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monitoring. Our study aligns with this evidence, confirming that a strong support system acts as a buffer against recurrence.

Clinical Implications

This nomogram is not just a statistical exercise; it is a call to action for nursing practice. We propose a "Traffic Light" discharge protocol based on the nomogram score (derived from tertiles of predicted risk):

- Green (Low Risk, Score < 100): Standard education.
- Yellow (Moderate Risk, Score 100–150): Enhanced education with teach-back, monthly tele-nursing.
- Red (High Risk, Score > 150): Intensive case management, referral to social work, and consideration for remote temperature monitoring devices to detect early signs of complications.[31]

Limitations

This was a single-center retrospective study. The single-center design may limit generalizability, and the lack of external validation in an independent patient cohort is a key limitation, which leaves the current model susceptible to the risk of overfitting to our specific institutional population; therefore, future multi-center studies are required. Although inter-rater reliability was checked, subjectivity in nursing assessments can introduce bias. We did not capture the specific off-loading modalities (eg, TCC vs. removable devices) which could influence risk. Additionally, we did not include novel inflammatory biomarkers (eg, IL-6, TNF-α), specific peripheral neuropathy severity assessments, or medication adherence data, which are important factors. Furthermore, predicting long-term (2–5 years) recurrence is vital for chronic DFU management, and our model is restricted to a 1-year window.

Conclusion

We developed and validated a nursing-integrated nomogram that accurately predicts 1-year ulcer recurrence in DFU patients after vascular intervention. By combining HbA1c and WIfI stage with Self-Care Agency, Adherence, and Social Support, this tool highlights the indispensable value of nursing assessment in limb salvage. It provides a practical, evidence-based method for stratifying patients and customizing preventative care.

Abbreviations

AUC, Area Under the Curve; BMI, Body Mass Index; CI, Confidence Interval; CRP, C-Reactive Protein; DCA, Decision Curve Analysis; DFU, Diabetic Foot Ulcer; ESCA, Exercise of Self-Care Agency; EVT, Endovascular Therapy; HbA1c, Hemoglobin A1c; LASSO, Least Absolute Shrinkage and Selection Operator; OR, Odds Ratio; PAD, Peripheral Arterial Disease; PTA, Percutaneous Transluminal Angioplasty; ROC, Receiver Operating Characteristic; SSRS, Social Support Rating Scale; WIfI, Wound, Ischemia, and foot Infection.

Data Sharing Statement

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of Wuhan No.6 Hospital, Affiliated Hospital of Jianghan University (WHSHIRB-K-2025009). The requirement for informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Author Contributions

LF: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

WZ: Investigation, Validation, Data curation, Writing – review & editing.

HD: Investigation, Validation, Writing – review & editing.

ZC: Formal analysis, Methodology, Writing – review & editing.

XC: Conceptualization, Supervision, Project administration, Funding acquisition, Writing – review & editing.

All authors gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

References

1. McDermott K, Fang M, Boulton AJM, Selvin E, Etiology HCW. Epidemiology, and disparities in the burden of diabetic foot ulcers. *Diab Care*. 2023;46(1):209–221. doi:10.2337/dci22-0043
2. Qi X, Li Y, Xiang Y, et al. Hyperthermia-enhanced immunoregulation hydrogel for oxygenation and ROS neutralization in diabetic foot ulcers. *Cell Biomat*. 2025;1(3). doi:10.1016/j.celbio.2025.100020
3. Cheng S, Wang H, Pan X, et al. Dendritic hydrogels with robust inherent antibacterial properties for promoting bacteria-infected wound healing. *ACS Appl Mater Interfaces*. 2022;14(9):11144–11155. doi:10.1021/acsami.1c25014
4. Azhar A, Basheer M, Abdelgawad MS, Roshdi H, Kamel MF. Prevalence of peripheral arterial disease in diabetic foot ulcer patients and its impact in limb salvage. *Int J Low Extrem Wounds*. 2023;22(3):518–523. doi:10.1177/15347346211027063
5. Bódis KB, Florea DI, Goh S, et al. PTA-DFS study: design of a randomised controlled trial assessing the effects of early percutaneous transluminal angioplasty on the healing of diabetic foot ulcers in persons with type 2 diabetes. *BMC Cardiovasc Disord*. 2025;25(1):811. doi:10.1186/s12872-025-05288-1
6. Duarte EG, Lopes CF, Gaio DRF, et al. Brazilian society of angiology and vascular surgery 2023 guidelines on the diabetic foot. *J Vasc Bras*. 2024;23:e20230087. doi:10.1590/1677-5449.202300872
7. Armstrong DG, Boulton AJM, Bus SA. Diabetic foot ulcers and their recurrence. *N Engl J Med*. 2017;376(24):2367–2375. doi:10.1056/NEJMra1615439
8. Lin C, Tian J, Zhang Z, Zheng C, Liu J. Risk factors associated with the recurrence of diabetic foot ulcers: a meta-analysis. *PLoS One*. 2025;20(2):e0318216. doi:10.1371/journal.pone.0318216
9. Yang B, Zha X, Ding Y. Risk factors associated with amputation for patients with diabetic foot ulcers: a retrospective study. *Diabetes Metab Syndr Obes*. 2024;17:4201–4209. doi:10.2147/dmso.S490614
10. Armstrong NS, Armstrong AA, Mills JL, et al. Three-year recurrence in people with diabetic foot ulcers and chronic limb threatening ischemia is comparable to cancer. *Int Wound J*. 2025;22(8):e70724. doi:10.1111/iwj.70724
11. Gallagher KA, Mills JL, Armstrong DG, et al. 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*. 2024;149(4):e232–e53. doi:10.1161/cir.0000000000001192
12. Ghaemi SN. The rise and fall of the biopsychosocial model. *Br J Psychiatry*. 2009;195(1):3–4. doi:10.1192/bjp.bp.109.063859
13. Wade DT, Halligan PW. The biopsychosocial model of illness: a model whose time has come. *Clin Rehabil*. 2017;31(8):995–1004. doi:10.1177/0269215517709890
14. Korbmacher M, Gurholt TP, de Lange AG, et al. Bio-psycho-social factors' associations with brain age: a large-scale UK Biobank diffusion study of 35,749 participants. *Front Psychol*. 2023;14:1117732. doi:10.3389/fpsyg.2023.1117732
15. Guo Q, Ying G, Jing O, et al. Influencing factors for the recurrence of diabetic foot ulcers: a meta-analysis. *Int Wound J*. 2023;20(5):1762–1775. doi:10.1111/iwj.14017
16. Son YJ, Choi J, Lee HJ. Effectiveness of nurse-led heart failure self-care education on health outcomes of heart failure patients: a systematic review and meta-analysis. *Int J Environ Res Public Health*. 2020;17(18). doi:10.3390/ijerph17186559
17. Changsieng P, Pichayapinyo P, Lagampan S, Lapvongwatana P. Implementation of self-care deficits assessment and a nurse-led supportive education program in community hospitals for behavior change and HbA1c reduction: a cluster randomized controlled trial. *J Prim Care Community Health*. 2023;14:21501319231181106. doi:10.1177/21501319231181106
18. Wantonoro W, Komarudin K, Imania DR, Harun S, Nguyen TV. The influence of 6-month interdisciplinary accompaniment on family caregivers' knowledge and self-efficacy regarding diabetic wound care. *SAGE Open Nurs*. 2023;9:23779608231167801. doi:10.1177/23779608231167801
19. Collins GS, Reitsma JB, Altman DG, Moons KG. Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD): the TRIPOD statement. *BMJ*. 2015;350:g7594. doi:10.1136/bmj.g7594
20. Kearney BY, Fleischer BJ. Development of an instrument to measure exercise of self-care agency. *Res Nurs Health*. 1979;2(1):25–34. doi:10.1002/nur.4770020105
21. Crews RT, Shen BJ, Campbell L, et al. Role and determinants of adherence to off-loading in diabetic foot ulcer healing: a prospective investigation. *Diab Care*. 2016;39(8):1371–1377. doi:10.2337/dc15-2373
22. Zhou Y, Cao Z, Yang M, et al. Comorbid generalized anxiety disorder and its association with quality of life in patients with major depressive disorder. *Sci Rep*. 2017;7:40511. doi:10.1038/srep40511

23. Friedman J, Hastie T, Tibshirani R. Regularization paths for generalized linear models via coordinate descent. *J Stat Softw*. 2010;33(1):1–22.
24. Portet S. A primer on model selection using the Akaike Information Criterion. *Infect Dis Model*. 2020;5:111–128. doi:10.1016/j.idm.2019.12.010
25. Vickers AJ, van Calster B, Steyerberg EW. A simple, step-by-step guide to interpreting decision curve analysis. *Diagn Progn Res*. 2019;3:18. doi:10.1186/s41512-019-0064-7
26. Zhang Y, Zhang B, Chen C, Feng X, Song S, Wang H. The mediation effect of attitude on the association between knowledge and self-management behaviors in Chinese patients with diabetes. *Int J Public Health*. 2023;68:1606022. doi:10.3389/ijph.2023.1606022
27. Zhu X, Lee ES, Chan FHF, Lim PXH, Chen YC, Griva K. Foot self-care behaviour in primary care patients with diabetic foot ulcers: structural equation modelling of psychological predictors. *Int Wound J*. 2024;21(5):e14897. doi:10.1111/iwj.14897
28. Tansley J, Collings R, Williams J, Paton J. Off-loading and compression therapy strategies to treat diabetic foot ulcers complicated by lower limb oedema: a scoping review. *J Foot Ankle Res*. 2023;16(1):56. doi:10.1186/s13047-023-00659-3
29. Ababneh A, Finlayson K, Edwards H, Lazzarini PA. Factors associated with adherence to using removable cast walker treatment among patients with diabetes-related foot ulcers. *BMJ Open Diabetes Res Care*. 2022;10(1). doi:10.1136/bmjdrc-2021-002640
30. Luo R, Ji Y, Liu YH, Sun H, Tang S, Li X. Relationships among social support, coping style, self-stigma, and quality of life in patients with diabetic foot ulcer: a multicentre, cross-sectional study. *Int Wound J*. 2023;20(3):716–724. doi:10.1111/iwj.13914
31. Shih CD, Scholten HJ, Ripp G, et al. Effectiveness of a continuous remote temperature monitoring program to reduce foot ulcers and amputations: multicenter postmarket registry study. *JMIR Diabetes*. 2024;9:e46096. doi:10.2196/46096