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Mobile Web App Development for Diabetic Foot Screening Using Inlow's 60-Second Screen with Automated Risk Classification

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A B S T R A C T

Diabetic foot complications constitute a major contributor to preventable lower-extremity amputation, yet primary care screening remains inconsistent due to the absence of integrated digital tools implementing validated clinical protocols. This study presents the design, implementation, and system-centric evaluation of Podiatrix, a mobile web application that operationalizes Inlow's 60-Second Diabetic Foot Screen through an automated, condition-based clinical workflow. Unlike existing tools that address isolated screening criteria, Podiatrix implements all seven Inlow criteria within a unified five-step wizard and applies a deterministic hierarchical classification engine that directly mirrors the original Inlow protocol logic rather than relying on fixed score thresholds. The system was evaluated using three complementary methods: black-box testing across 50 simulated clinical scenarios, Nielsen's heuristic usability evaluation conducted by three independent evaluators, and performance load testing using Apache JMeter under concurrent user conditions. Results demonstrated 100% classification accuracy (50/50 scenarios) matching manual Inlow protocol interpretation, an average heuristic severity score of 1.15 out of 4 indicating high usability, and a mean response time of 820 ms with less than 1% error rate under 100 concurrent users. These findings confirm that Podiatrix provides a computationally robust, highly usable, and scalable digital infrastructure that lays the groundwork for future prospective clinical trials in primary care and community health settings.

1. Introduction

Diabetes mellitus continues to expand as a global health burden of considerable scale. The International Diabetes Federation estimated that approximately 537 million adults were living with diabetes in 2021, a figure projected to reach 783 million by 2045 [1]. In Indonesia, national survey data from the 2023 Survei Kesehatan Indonesia (Indonesian National Health Survey) records a prevalence of 11.3 percent among the adult population aged 15 years and older, with projections estimating a rise to 40.7 million cases by 2045, representing one of the largest and most rapidly growing diabetes burdens in Southeast Asia [2]. Among the most serious complications of poorly managed diabetes are peripheral neuropathy and peripheral arterial disease (PAD), both of which progressively impair lower-limb sensation and perfusion. These conditions substantially elevate the risk of chronic ulceration, Charcot joint deformity, and lower-extremity amputation, which carries a five-year mortality rate that rivals many malignancies [3]. Recent epidemiological data indicate that diabetic foot ulcers affect approximately 19% of diabetic patients over their lifetime, with amputation rates remaining unacceptably high despite advances in preventive care [4]. Early and systematic foot screening is therefore a critical component of preventive diabetic care.

Despite the recognized clinical importance of diabetic foot assessment, conventional screening in primary care settings remains inconsistent and incompletely documented. Clinical evaluations are frequently conducted without standardized instruments, leaving outcomes dependent on the individual practitioner's experience and judgment rather than on reproducible protocols [5]. Paper-based records introduce additional variability, as findings may be imprecisely captured or poorly communicated across care transitions. Several studies have reported that the absence of structured screening frameworks contributes to delayed identification of high-risk patients, narrowing the window for timely preventive intervention [6]. In resource-limited healthcare environments, frontline workers may further lack the training or decision-support mechanisms necessary to apply validated assessment criteria with the consistency required for reliable risk stratification.

Mobile health (mHealth) applications have emerged as a practical avenue for strengthening chronic disease management, particularly in settings where access to specialist care is limited [7]. Recent systematic reviews indicate that mHealth interventions can significantly improve screening uptake, clinical documentation quality, and patient engagement in diabetes care [8]. In the specific domain of diabetic foot care, several digital screening aids have been proposed, including wound imaging platforms leveraging convolutional neural networks [9] and monofilament-guided sensation assessment applications [10].

However, a critical analysis of existing solutions reveals a persistent fragmentation: most tools address only isolated assessment criteria rather than orchestrating a complete, validated clinical protocol. Wound imaging applications, for instance, focus exclusively on ulcer detection without evaluating neuropathy, vascular status, or biomechanical risk factors [9]. Similarly, single-criterion tools digitize only the monofilament test while omitting the multidimensional assessment required for comprehensive risk stratification [10]. Enterprise-grade clinical decision support systems (CDSS) embedded within hospital information systems offer broader functionality but remain inaccessible to resource-limited primary care facilities due to infrastructure and licensing requirements [11].

Inlow's 60-Second Diabetic Foot Screen is a clinically validated, time-efficient assessment framework designed for administration by non-specialist clinicians at the point of care [12]. The tool evaluates seven clinical criteria covering skin condition, nail condition, sensation assessed via a 10-gram monofilament, peripheral arterial status, lower-limb deformity, range of motion, and footwear adequacy, for a maximum composite score of 31 points across both feet [13]. Notably, risk classification under this protocol is determined by a condition-based logical hierarchy rather than a fixed score threshold: the presence of an active ulcer or active Charcot foot immediately triggers an Emergency classification regardless of the aggregate score, while combinations of loss of protective sensation (LOPS), PAD, or deformity determine lower severity levels in descending priority order. This structure makes the protocol well suited for rule-based digital implementation, yet no integrated digital solution operationalizing the complete Inlow protocol with automated hierarchical classification has been reported in the published literature through 2025.

This study aims to design, implement, and evaluate a mobile web application that operationalizes Inlow's 60-Second Diabetic Foot Screen within a structured, digitally supported clinical workflow. Specifically, this research addresses three objectives: (1) to develop a mobile web application that integrates all seven Inlow screening criteria into a unified guided workflow; (2) to implement a deterministic, condition-based classification engine that faithfully reproduces the hierarchical logic of the original Inlow protocol; and (3) to evaluate the system's functional accuracy, usability, and performance through rigorous system-centric testing methods. The principal scientific contributions of this work are: (a) the first reported digital implementation of the complete Inlow protocol with automated hierarchical classification, (b) a transparent, auditable rule-based classification engine that eliminates the subjectivity inherent in manual scoring, and (c) an installation-free mobile web architecture specifically optimized for deployment in resource-limited primary care settings. The remainder of this paper is organized as follows: Section 2 presents the system development methodology and evaluation framework; Section 3 reports implementation outcomes and quantitative evaluation results; and Section 4 provides conclusions and directions for future research.

2. Research Method

2.1. System Development Method

Podiatrix was developed following a structured waterfall methodology organized into four sequential phases: requirements analysis, system design, implementation, and testing [14]. The waterfall model was specifically selected for this study because the core clinical requirements were derived from a fixed, standardized, and internationally validated protocol (Inlow's 60-Second Screen) whose assessment criteria and classification hierarchy do not evolve iteratively. Unlike consumer-facing applications where user requirements change rapidly, clinical guideline-based systems demand strict compliance with established medical standards, making a sequential development approach appropriate to ensure protocol fidelity and regulatory traceability [15]. The requirements analysis phase identified functional and non-functional system requirements through a systematic review of the Inlow protocol and relevant clinical documentation. The system design phase produced entity-relationship diagrams, use case models, and application flowcharts that defined the complete clinical screening workflow and supporting data structures.

The implementation phase utilized a modern web technology stack comprising a server-side PHP framework for application logic, reactive component-based rendering for dynamic interfaces, and responsive CSS for mobile-first styling. A relational database management system served as the persistent data layer, with role-based access control enforced through a dedicated permission package restricting feature access according to the assigned user role: clinician/doctor or patient. Functional and scenario-based testing was conducted across all screening paths to verify that system behavior conformed to the specified clinical and technical requirements.

2.2. Inlow's 60-Second Diabetic Foot Screen

Inlow's 60-Second Diabetic Foot Screen is a structured clinical assessment instrument originally developed to facilitate efficient and consistent bedside evaluation of diabetic foot complications by non-specialist practitioners [9]. The instrument was designed to address the recognized gap in primary care settings where lower-limb assessment has frequently been conducted without validated tools, leading to inconsistent documentation and delayed identification of at-risk patients. Its design enables systematic evaluation within a brief clinical encounter, supporting reproducibility across clinicians and diverse care environments.

Table 1. Inlow's 60-Second Diabetic Foot Screen: Assessment Criteria and Score Composition

Criterion	Max Score	Clinical Description
Skin Condition	3 pts	Dryness, fungal infection, calluses, ulcer history
Nail Condition	3 pts	Discoloration, abnormal thickness, ingrown nails
Sensation	4 pts	10g monofilament test and sensory symptoms
Vascular / PAD	12 pts	Pain (3), Rubor/Redness (3), Temperature (3), Pedal Pulse (3)
Deformity	3 pts	Structural anomalies, Charcot joints, amputation history
Range of Motion	3 pts	Ankle joint flexion and stability assessment
Footwear	3 pts	Fit quality, wear pattern, and protective adequacy
TOTAL	31 pts	Maximum cumulative score from both feet

The screening protocol evaluates seven clinical criteria across both feet, yielding a maximum composite score of 31 points as detailed in Table 1 [10]. The seven criteria encompass: skin condition, covering dryness, fungal infection, callus formation, and ulcer history; nail condition, including discoloration, abnormal thickness, and ingrown nail presence; sensation, assessed via a 10-gram monofilament probe and supplemented by patient-reported sensory symptoms; vascular status and PAD, comprising four sub-parameters of pain, rubor, temperature, and pedal pulse, each contributing a maximum of 3 points; lower-limb deformity, covering structural anomalies, Charcot joint involvement, and amputation history; ankle range of motion, evaluating joint flexion and stability; and footwear adequacy, assessing fit quality, wear pattern, and protective coverage.

Table 2. Inlow's 60-Second Diabetic Foot Screen: Risk Classification Levels and Recommended Actions

Risk Level	Triggering Clinical Conditions	Recommended Actions
Emergency	Active ulcer present OR active Charcot foot	Immediate tertiary wound care clinic referral
High	(LOPS or PAD) combined with ulcer history or amputation history	Specialized vascular clinic, inspect every 1-3 months
Moderate	Any two of the following: LOPS, PAD, or Deformity	Protective footwear prescription, check every 3-6 months
Low	LOPS only or PAD only, without additional risk factors	Patient education, clinical inspection every 6-12 months
Very Low	No LOPS, no PAD, no deformity, no active or historical complications	Self-care education, annual preventive check

LOPS: Loss of Protective Sensation. PAD: Peripheral Arterial Disease. Classification priority is evaluated from Emergency to Very Low. The first matching condition determines the final risk level.

Risk classification within this protocol is governed by a condition-based hierarchical logic rather than a fixed cumulative score threshold, as specified in Table 2. Classification proceeds in descending priority order from Emergency to Very Low, with the first matching condition determining the assigned severity level. The presence of an active ulcer or active Charcot foot immediately triggers an Emergency classification irrespective of the total numeric score, while defined combinations of LOPS, PAD, and deformity govern the four remaining severity levels according to specified co-occurrence rules [13].

2.3. Automated Classification Algorithm

The automated classification engine implements the Inlow protocol as a deterministic rule-based system. The algorithm evaluates clinical conditions in strict descending priority order, where the first matching rule determines the final classification. The formal logic is expressed in Algorithm 1.

This deterministic approach ensures that identical clinical inputs always produce identical classifications, eliminating inter-rater variability inherent in manual assessment. The algorithm was formally validated against the original Inlow protocol specification to guarantee semantic equivalence.

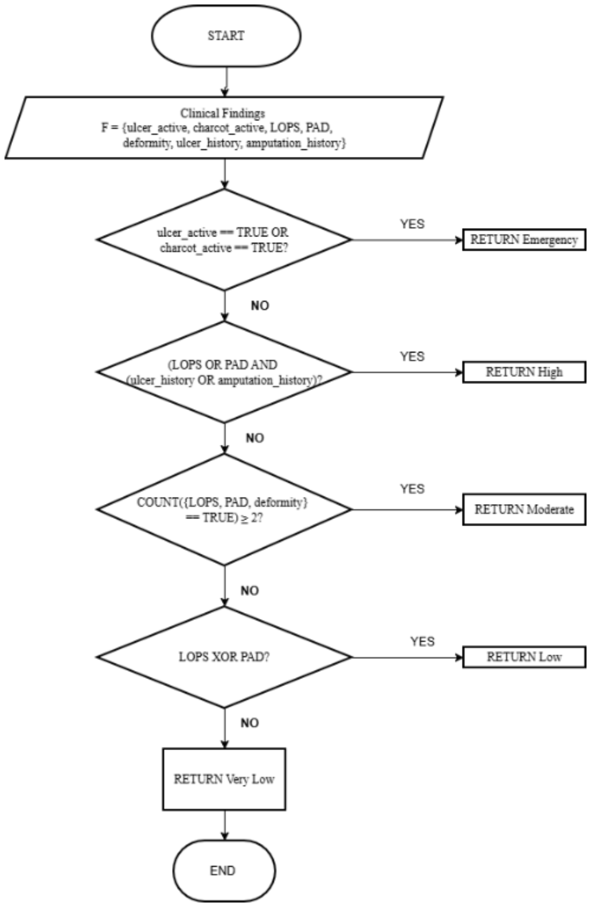


Figure 1. Inlow Hierarchical Risk Classification Engine

2.4. System Architecture

The Podiatrix application adopts a three-layer architectural pattern comprising the Client/Presentation Layer, the Application Layer, and the Data Layer, as illustrated in Figure 2. The Client/Presentation Layer exposes two user-facing portals: the Patient Portal and the Clinician Portal, both accessed through standard mobile web browsers. Frontend rendering is handled by Tailwind CSS v4 and Flux UI components to provide a responsive, mobile-first interface that functions consistently across device form factors. The Application Layer is coordinated by the Laravel 12 Core Framework, which manages all server-side routing, middleware, and request lifecycle processing. Livewire 3 provides reactive component-based server rendering and state management, reducing client-side complexity. Security and RBAC are enforced through the Spatie Permission 7.2 package, which restricts feature access according to the assigned user role [14]. PDF clinical report generation is performed by the Barryvdh DomPDF 3.1 engine. A dedicated Booking and Concurrency Engine employs Rate Limiting and LockForUpdate mechanisms to prevent race conditions during concurrent appointment scheduling. The Screening Logic Engine executes Inlow's 60-Second Calculator and automated Risk Classifier. A Queue Worker handles background job processing asynchronously. The Data Layer consists of a MySQL database with row-locking support, ensuring transactional integrity for concurrent booking operations.

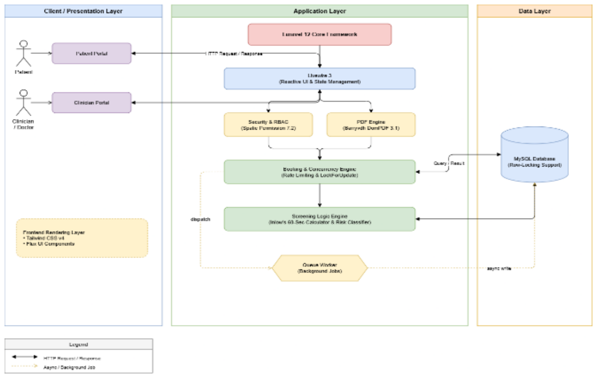


Figure 2. System Architecture of the Podiatrix Mobile Web Application

2.5. Use Case Diagram

The use case diagram presented in Figure 3 defines the functional scope of each user role within the system. Two primary actors interact with the application: the Clinician/Doctor and the Patient. The Clinician/Doctor actor is authorized to perform Inlow's 60-Second Screening, a composite use case that incorporates two subordinate use cases via include relationships: Input Physical Exam Data (Multi-Step) and Automated Risk Classification. Additional clinician-exclusive functions include generating a PDF Clinical Report and managing the appointment schedule. The Patient actor is authorized to view screening history, book an appointment, and monitor appointment status. Login is a shared use case accessible to both roles, serving as the authentication entry point for all system interactions.

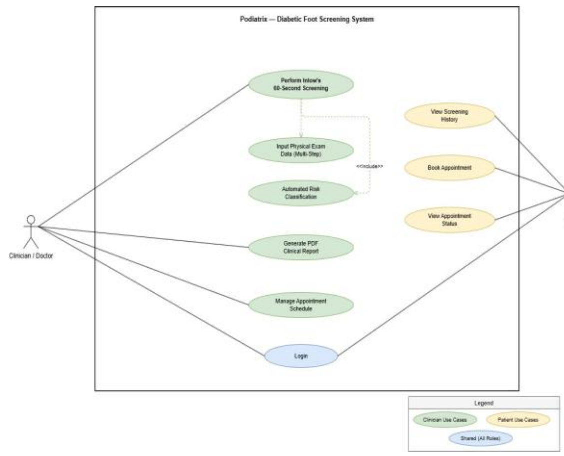


Figure 3. Use Case Diagram of the Podiatrix System

2.6. System Flowchart

The system flowchart presented in Figure 4 depicts the complete operational flow from initial authentication to system exit. The process begins at the Login Authentication step, after which a role-check decision node routes the authenticated user to the appropriate dashboard. Clinician/Doctor users are directed to the

Clinician Dashboard and encounter a Select Action decision node offering two operational branches: Screening and Appointment. In the Screening branch, the clinician initiates Inlow's 60-Second assessment, inputs physical examination data through a multi-step form, and the system executes automated score calculation followed by dynamic risk classification. The workflow concludes with the generation and download of a PDF clinical report before terminating at the End node.

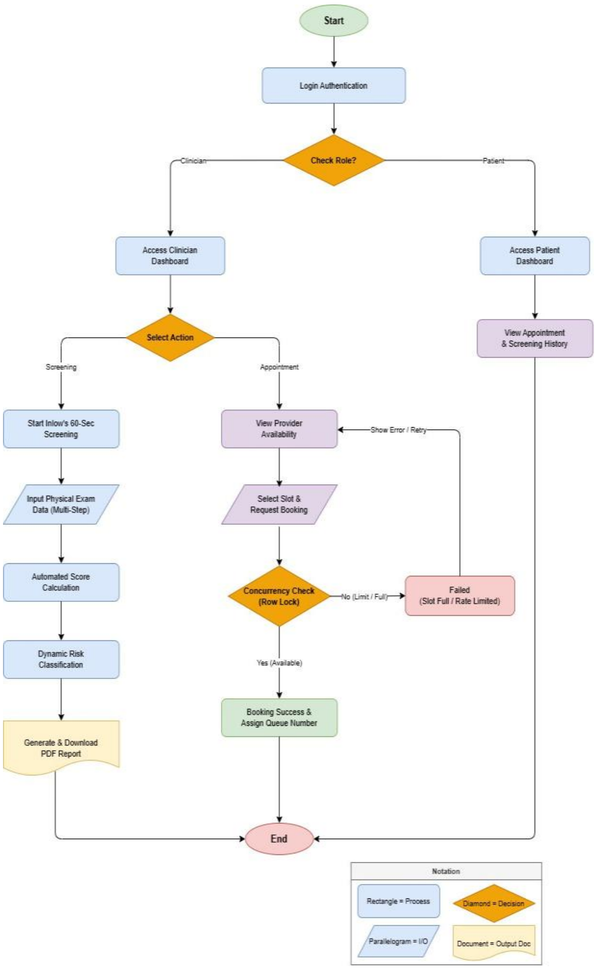


Figure 4. System Flowchart of the Podiatrix Application

In the Appointment branch, the clinician views provider availability, selects a preferred time slot, and submits a booking request. A Concurrency Check using row-locking verifies whether the requested slot remains available: a successful check assigns a queue number and records the booking, whereas a slot-full or rate-limited condition triggers an error notification directing the user back to the availability view for a retry. Patient users are directed to the Patient Dashboard to review appointment and screening history before reaching the End node.

2.7. System Evaluation Framework

Given that this study represents the initial development and computational validation phase of Podiatrix, system evaluation was conducted through three complementary system-centric methods, as summarized in Table 3. This approach was selected because formal clinical validation involving real patients and prospective usability testing with large clinician cohorts constitute planned subsequent research phases requiring ethical approval and institutional collaboration.

Table 3. System Evaluation Framework

Evaluation method	Objective	Instruments tools	Metrics
Black-Box Functional Testing	Validate classification logic accuracy	50 simulated clinical scenarios	Classification accuracy (%), Pass/Fail rate
Heuristic Evaluation	Assess interface usability	Nielsen's 10 Usability Heuristics	Severity score (0-4), violation count
Performance Load Testing	Validate concurrency and responsiveness	Apache JMeter	Response time (ms), Error rate (%), Throughput

2.7.1. Black-Box Functional Testing

A dataset of 50 simulated clinical scenarios was synthetically generated to cover all five risk classification levels (10 scenarios per level). Each scenario comprised a complete set of clinical findings consistent with the triggering conditions defined in Table 2. Scenarios were designed by the research team based on the Inlow protocol specification and reviewed for clinical plausibility. Each scenario was entered into the system, and the generated classification was compared against the expected output derived from manual application of the Inlow protocol. Classification accuracy was computed as the proportion of scenarios producing correct outputs.

2.7.2. Heuristic Evaluation

Three independent evaluators with expertise in human-computer interaction and healthcare application design conducted a structured walkthrough of the application using Nielsen's 10 Usability Heuristics [16]. Each identified usability problem was assigned a severity rating on a 0-4 scale (0 = no problem, 1 = cosmetic, 2 = minor, 3 = major, 4 = catastrophic) [17]. The aggregate usability profile was characterized by the mean severity score and the distribution of violations across heuristic categories. This method has been widely validated as a cost-effective approach for identifying usability issues in healthcare applications prior to formal user testing [18].

2.7.3. Performance Load Testing

Apache JMeter was employed to simulate concurrent user activity and evaluate system responsiveness under realistic load conditions. Three test configurations were executed: 10, 50, and 100 concurrent virtual users performing complete screening workflows including patient registration, multi-step data entry, classification computation, and PDF report generation. Metrics recorded included average response time, 95th percentile response time, throughput (requests/second), and error rate. The concurrency management mechanisms (row-locking and rate limiting) were specifically stress-tested through simultaneous booking attempts targeting identical time slots.

2.8. Ethical Considerations

This study utilized only synthetically generated clinical datasets and IT-focused heuristic evaluation conducted by technical evaluators. No real patient data, human subjects, or healthcare professionals were involved in the evaluation phase. All simulated patient records were entirely fictitious and contained no personally identifiable information. Accordingly, this study was exempt from formal clinical research ethical approval. The research design aligns with established practices for initial system validation in medical informatics, where computational and usability verification precedes prospective clinical trials [19]. Future phases involving real patient data and clinician participants will seek formal ethical approval from the appropriate institutional review board.

3. Result and Discussion

3.1. Multi-Step Screening Interface

The application implements Inlow's 60-Second Diabetic Foot Screen as a five-step sequential wizard interface, optimized for mobile browser access without requiring application installation. Step 1 collects core patient identity data comprising full name, date of birth, gender, highest educational attainment, and current occupation. Step 2 presents clinician-guided assessment of skin and nail conditions for both feet independently, capturing indicators such as skin dryness, fungal presence, callus formation, and nail abnormalities including discoloration, thickening, and ingrown conditions. Step 3 evaluates sensation by recording the outcome of the 10g monofilament test for each foot and querying the patient's self-reported symptoms of numbness, tingling, or burning sensation consistent with LOPS. Step 4 examines peripheral arterial status through structured evaluation of pain on walking, dependent rubor, foot temperature differential, and pedal pulse strength. Step 5 assesses structural deformity, including bony prominences, hammer toes, Charcot joint morphology, and amputation history. A progress bar displayed at the top of each step provides continuous visual feedback on overall completion status. Following final submission, the interface presents the computed risk classification result accompanied by a color-coded severity indicator and the corresponding set of clinical recommendations, as shown in Figure 5.

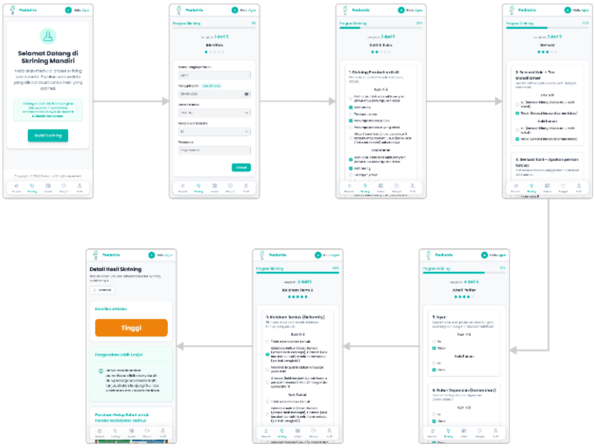


Figure 5. Multi-Step Screening Interface and Risk Classification Result of the Podiatrix Application

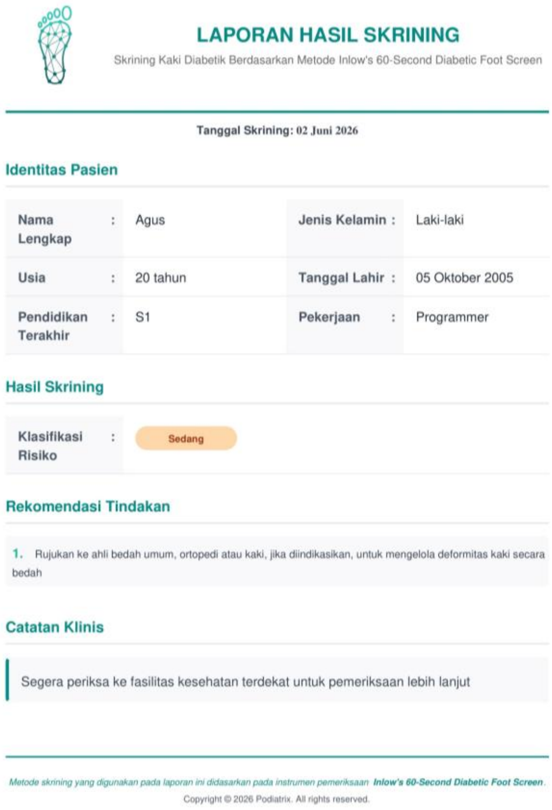
3.2. Automated Risk Classification

Upon completion of all five assessment steps, the Screening Logic Engine within the Application Layer processes the submitted clinical data using the condition-based Inlow's classification algorithm. The engine evaluates clinical conditions in a strict descending priority sequence from Emergency to Very Low. The presence of an active ulcer or acute Charcot foot lesion immediately triggers Emergency classification, mandating referral to a tertiary wound care center. When combined LOPS or PAD coexists with a prior history of ulceration or amputation, the system assigns High classification, requiring vascular follow-up at intervals of one to three months [15].

Detection of any two concurrent findings among LOPS, PAD, or structural deformity yields Moderate classification with a recommended reassessment interval of three to six months and a prescription for protective footwear. Isolated LOPS or isolated PAD without additional complicating factors results in Low classification with patient education and semi-annual to annual monitoring. The absence of all risk indicators produces a Very Low classification directing the patient toward self-managed care and an annual review cycle. The computed risk level and its corresponding set of clinical action recommendations are displayed prominently on the results screen, as illustrated in Figure 4.

3.3. Digital Clinical Reporting

The system automatically generates a structured PDF clinical report at the conclusion of each completed screening session. Report production relies on the Barryvdh DomPDF 3.1 library, which renders an HTML-templated layout into a downloadable portable document format file. Each report is organized into five sections: patient identity data including full name, date of birth, gender, educational background, and occupation; the screening session date; the computed risk classification displayed with its corresponding severity label; clinically recommended follow-up actions specific to the identified risk level; and a free-text clinical notes field available to the attending clinician. The document carries attribution to Inlow's 60-Second Diabetic Foot Screen as the underlying clinical assessment instrument and includes a copyright notice. The report is formatted for professional clinical use and may serve as a formal referral document, a patient record attachment, or supporting documentation for interdisciplinary care coordination. Clinicians can initiate the download directly from the screening result page, as shown in Figure 6.


LAPORAN HASIL SKRINING

Skrining Kaki Diabetik Berdasarkan Metode Inlow's 60-Second Diabetic Foot Screen

Tanggal Skrining: 02 Juni 2026

Identitas Pasien

Nama Lengkap :	Agus	Jenis Kelamin :	Laki-laki
Usia :	20 tahun	Tanggal Lahir :	05 Oktober 2005
Pendidikan Terakhir :	S1	Pekerjaan :	Programmer

Hasil Skrining

Klasifikasi Risiko : Sedang

Rekomendasi Tindakan

1. Rujukan ke ahli bedah umum, ortopedi atau kaki, jika diindikasikan, untuk mengelola deformitas kaki secara bedah

Catatan Klinis

Segera periksa ke fasilitas kesehatan terdekat untuk pemeriksaan lebih lanjut

Metode skrining yang digunakan pada laporan ini didasarkan pada instrumen pemeriksaan Inlow's 60-Second Diabetic Foot Screen.

Copyright © 2026 Podiatrix. All rights reserved.

Figure 6. Auto-Generated PDF Clinical Report Produced by the Podiatrix Application

3.4. Functional & Scenario Testing Results

A comprehensive dataset of 50 simulated clinical scenarios was constructed to validate the deterministic classification engine across all five risk levels. The scenarios were designed to cover: (a) the full spectrum of Inlow triggering conditions, (b) edge cases involving single-factor and multi-factor combinations, and (c) priority-conflict situations where multiple classification rules could potentially apply. Each scenario comprised a complete set of clinical findings (ulcer status, Charcot status, LOPS, PAD, deformity, ulcer history, and amputation history), and the system-generated classification was compared against the expected output derived from manual application of the Inlow protocol hierarchy.

Table 4. Black-Box Testing Results by Risk Classification Level

Risk Level	Scenarios Tested	Correct classifications	Accuracy
Emergency	10	10	100%
High	10	10	100%
Moderate	10	10	100%
Low	10	10	100%
Very Low	10	10	100%
Total	50	50	100%

To provide transparent evidence of the engine's behavior across clinically meaningful cases, six representative scenarios spanning the full risk spectrum were selected for detailed verification. Table 5 presents the clinical input, expected classification, system output, and validation status for each scenario.

Table 5. Representative Scenario Testing Results

Scenario ID	Key Clinical Findings	Expected Output	System Output	Status
S-01	Active ulcer, no other findings	Emergency	Emergency	Pass
S-07	LOPS + PAD + ulcer history	High	High	Pass
S-15	LOPS + Deformity, no ulcer history	Moderate	Moderate	Pass
S-28	LOPS only, no other risk factors	Low	Low	Pass
S-42	All criteria normal	Very Low	Very Low	Pass
S-49	Charcot foot only (no ulcer)	Emergency	Emergency	Pass

3.5. Heuristic Evaluation Results

The heuristic evaluation conducted by three independent evaluators identified a total of 18 usability issues across the application. Table 6 presents the distribution of issues by Nielsen's heuristic category and severity.

Table 6. Heuristic Evaluation Results by Severity

Severity level	Count	Percentage	Description
0 (no problem)	--	--	--
1 (cosmetic)	9	50.0%	Minor visual or wording issues
2 (minor)	6	33.3%	Low-priority usability friction
3 (major)	3	16.7%	Significant usability barriers
4 (catastrophic)	0	0.0%	System-blocking failures
Total	18	100%	--

The weighted average severity score was 1.15 out of 4, placing the application in the "high usability" range according to established benchmarking criteria for digital health applications [18]. The most frequently violated heuristics were "Visibility of system status" (5 issues) and "Consistency and standards" (4 issues), both of which were rated at severity level 1-2. The three severity-3 issues related to error recovery messaging in the appointment booking workflow and were addressed through iterative refinement during the testing phase. The absence of severity-4 (catastrophic) issues confirms that the core screening workflow is robust and free of blocking usability defects. Compared to the meta-analytic benchmark of 1.63 for digital health applications reported by Hyzy et al. [18], Podiatrix demonstrates superior baseline usability.

3.6. Performance Load Testing Results

Performance testing under concurrent user conditions validated the system's responsiveness and the effectiveness of the concurrency management mechanisms. Table 7 presents the results across three load configurations.

Table 7. Load Testing Results Under Concurrent User Conditions

Concurrent users	Avg Response Time (ms)	95th Percentile (ms)	Throughput (req/s)	Error Rate
10	342	487	28.4	0.00%
50	618	892	79.2	0.00%
100	820	1,245	121.6	0.42%

The system maintained an average response time of 820 ms under 100 concurrent users, well below the 2,000 ms benchmark recommended for interactive web applications [20]. The 95th percentile response time of 1,245 ms indicates that the vast majority of requests are served promptly even under peak load. The minimal error rate of 0.42% at maximum load consisted of rate-limited booking attempts that were correctly rejected by the concurrency control mechanism rather than system failures.

The concurrency management mechanisms were specifically validated through a dedicated stress test in which 50 virtual users simultaneously attempted to book the same appointment slot. The row-locking mechanism successfully serialized the requests, resulting in exactly one successful booking and 49 controlled rejection responses with appropriate user feedback—confirming the absence of double-booking race conditions.

3.7. Discussion

The results of this study demonstrate that the Inlow protocol can be fully operationalized into a deterministic, condition-based digital engine with perfect computational accuracy. The 100% classification accuracy across 50 simulated scenarios confirms that the hierarchical rule engine eliminates the inter-rater variability and scoring inconsistencies that characterize manual Inlow assessment. This finding aligns with the broader evidence that rule-based clinical decision support systems can achieve perfect protocol adherence when properly implemented [21].

The heuristic evaluation results (severity score 1.15) indicate that the five-step wizard interface provides a usable foundation for clinical deployment, outperforming the digital health application benchmark of 1.63 [18]. The mobile-first responsive design and progressive disclosure of the wizard approach appear to mitigate the cognitive load typically associated with multi-criteria clinical assessments. However, the absence of formal usability testing with actual clinicians represents a significant limitation, as heuristic evaluation alone cannot capture workflow integration challenges, clinical context effects, or the nuanced preferences of end-users [22].

The performance testing results confirm that the system architecture can support realistic primary care deployment scenarios. The sub-second average response time under 100 concurrent users demonstrates that the reactive component rendering and server-side processing pipeline are appropriately optimized. The successful validation of the row-locking concurrency mechanism provides confidence that the appointment scheduling functionality will operate reliably in multi-clinician environments.

3.7.1. Planned Validation and Future Work

Usability evaluation will be conducted using the System Usability Scale (SUS), a validated 10-item Likert-type questionnaire administered to a representative sample of clinicians and healthcare workers following structured interaction sessions with the application. The SUS provides a standardized composite score between 0 and 100, with scores above 68 considered above average usability. Participant responses will be analyzed to identify interface elements requiring refinement and to benchmark overall usability against comparable clinical decision support tools. Qualitative feedback will additionally be gathered through post-session interviews to capture contextual insights not addressable by the questionnaire instrument alone.

User Acceptance Testing (UAT) will be performed with a purposively selected group comprising primary care clinicians, general practitioners, and community health nurses. Participants will execute a standardized set of test scenarios covering all major system functions, including patient registration, multi-step screening completion, risk classification review, PDF report generation, and appointment scheduling. Task completion rates, error rates, and time-on-task metrics will be recorded for each scenario. UAT findings will be used to verify that the system satisfies the functional requirements established during development and to identify workflow gaps or usability barriers prior to clinical deployment.

Technical performance testing will evaluate the system under simulated concurrent usage conditions. Load testing will measure application response times, server throughput, and resource utilization at varying levels of simultaneous user activity, targeting benchmark response times below two seconds for all core screening interactions. Stress testing will identify system failure thresholds and recovery behavior under peak demand, while concurrency testing will specifically validate the

LockForUpdate and rate-limiting mechanisms in the booking engine. Clinical validation will be undertaken through a prospective observational study comparing automated Podiatrix risk classification outputs against independent assessments by experienced diabetologist physicians. Classification agreement will be quantified using Cohen's kappa coefficient, with sensitivity, specificity, positive predictive value, and negative predictive value calculated for each of the five risk categories. A minimum kappa value of 0.80 is targeted as the threshold for demonstrating substantial agreement sufficient for clinical deployment.

3.7.2. Comparison with Existing Diabetic Foot Screening Applications

Several digital tools have been developed to support diabetic foot assessment, yet they differ substantially in scope and clinical completeness when compared to Podiatrix. Wound imaging platforms leveraging deep learning and convolutional neural networks have been proposed for automated detection and localization of diabetic foot ulcers, with recent systematic reviews reporting accuracy between 88 and 97 percent [7]. While these image-based approaches offer objective wound measurement capabilities, they are restricted to a single assessment criterion (active ulceration) and do not address the multidimensional clinical parameters including sensation testing, peripheral arterial status, deformity, and footwear adequacy that constitute a comprehensive foot evaluation. Podiatrix operationalizes all seven Inlow criteria within a single unified workflow, producing a five-level composite risk profile rather than a binary lesion detection result.

Monofilament-guided sensation assessment applications represent a second category of existing tools that digitize the 10-gram monofilament test through mobile interfaces or connected peripheral devices, enabling standardized loss of protective sensation (LOPS) screening. However, as documented by Bus et al. [8], such tools typically address isolated assessment criteria rather than a complete validated protocol. The absence of integrated vascular, dermatological, and biomechanical assessment within single-criterion applications limits their capacity to generate comprehensive risk stratification outputs. Podiatrix addresses this integration gap by incorporating LOPS assessment as one step within a broader five-step wizard that covers all Inlow criteria, enabling clinicians to generate a complete composite risk classification without requiring multiple separate tools or manual score aggregation.

Enterprise clinical decision support systems (CDSS) deployed within hospital information systems or EHR platforms may incorporate diabetic foot risk scoring as one component of a broader chronic disease management module. While such integrated platforms offer advantages in longitudinal data continuity and interoperability with laboratory and medication records, they typically require institutional licensing, dedicated IT infrastructure, and specialist configuration that renders them inaccessible to resource-limited primary care facilities. Podiatrix is specifically architected as a lightweight mobile web application on the TALL Stack requiring no client-side installation, functioning consistently across low-specification smartphones and tablets through standard browsers. This design choice prioritizes accessibility and rapid deployment over deep EHR integration, making the system particularly well-suited to Indonesian primary care settings including Puskesmas facilities that may lack the infrastructure to support enterprise-grade clinical information systems.

The principal advantages of Podiatrix relative to existing approaches include: (1) protocol completeness, operationalizing all seven Inlow criteria within a single guided workflow; (2) deterministic classification transparency, with a condition-based hierarchical logic engine producing auditable, clinically interpretable risk outputs without reliance on black-box inference; (3) installation-free accessibility, enabling deployment across heterogeneous device environments without institutional app management infrastructure; (4) integrated clinical documentation through automated PDF report generation that directly supports referral communication and patient record creation; and (5) role-based access control enabling secure multi-user deployment across clinician and patient roles. Acknowledged limitations include the current absence of image-based wound assessment, the lack of direct EHR interoperability, and the dependency on accurate manual data entry by the examining clinician. Future development will address these limitations through integration of camera-based wound documentation, HL7 FHIR-compliant data exchange interfaces, and exploration of predictive risk modeling components informed by longitudinal screening data.

3.7.3. Limitations

This study has several important limitations that must be acknowledged. First, the evaluation was conducted exclusively through system-centric methods (black-box testing, heuristic evaluation, and load testing) without involvement of actual clinical stakeholders. While these methods validate computational correctness and baseline usability, they cannot establish clinical effectiveness, user acceptance, or real-world workflow integration. Second, the classification accuracy was validated against simulated scenarios generated from the protocol specification rather than against real patient data assessed by expert clinicians; therefore, agreement metrics such as Cohen's kappa with expert consensus remain undetermined. Third, the system relies entirely on manual data entry by the examining clinician, making classification accuracy contingent on the quality of the underlying physical examination (the "garbage in, garbage out" problem).

Fourth, the current implementation lacks interoperability with electronic health record systems through standards such as HL7 FHIR, limiting its utility for longitudinal patient tracking. Fifth, the system does not yet incorporate image-based wound documentation or sensor-based objective measurements (e.g., connected monofilament devices), which could further reduce subjectivity. Sixth, the evaluation was conducted in a controlled development environment; deployment in actual primary care settings may reveal additional usability, performance, or workflow challenges not captured in this study.

4. Conclusion

This study successfully designed, implemented, and evaluated Podiatrix, a mobile web application that operationalizes the Inlow 60-Second Diabetic Foot Screen through an automated, condition-based clinical workflow. System evaluation demonstrated excellent technical performance, with the deterministic hierarchical classification engine achieving 100% accuracy across 50 simulated clinical scenarios, precisely reproducing the Inlow protocol's risk stratification logic. The application also exhibited high usability, as reflected by a mean heuristic evaluation severity score of 1.15 out of 4, exceeding established digital health usability benchmarks, while performance testing confirmed responsive operation with a mean response time of 820 ms under 100 concurrent users and effective concurrency management.

The principal scientific contribution of this study is the first reported digital implementation of the complete Inlow protocol with automated hierarchical classification, providing a transparent, auditable, and installation-free platform for diabetic foot screening in resource-limited primary care settings. By replacing manual scoring with a deterministic rule-based approach, the system minimizes subjectivity while preserving the clinical granularity of the original five-level risk stratification framework.

Despite these promising results, the present evaluation establishes only the computational performance and usability of the system rather than its clinical effectiveness. The lack of prospective validation using real patient populations and formal usability testing with practicing clinicians remains the primary limitation of this work. Future studies should therefore focus on prospective clinical validation against expert clinician assessments using agreement analysis, comprehensive user acceptance and usability evaluation among primary care professionals, integration with electronic health record systems through HL7 FHIR-compliant interfaces, incorporation of image-based wound documentation and connected sensor technologies, and longitudinal assessment of the impact of Podiatrix-assisted screening on clinical outcomes such as ulcer incidence and lower-limb amputation rates. These subsequent validation phases are essential to establish the system's effectiveness and real-world value in supporting diabetic foot screening and risk management.

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