

Development of a clinical decision support system for lower-limb prosthetic prescription

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Abstract

Lower-limb prosthetic prescription is a complex process, and in Thailand, practice remains inconsistent because of the limited availability of ISPO Category I professionals and the absence of localized guidance. To address this gap, a clinical decision support system (CDSS) was developed to help standardize decision-making and improve the quality of amputee care. This study set out to evaluate whether the CDSS could enhance prescription accuracy, reduce decision time, and provide acceptable usability to its users. A prospective, simulation-based crossover trial was conducted, in which participants completed two standardized case vignettes—once with and once without CDSS support—in randomized order. Completion time was automatically recorded, and outcomes included component-level accuracy, decision time, and usability as measured by the System Usability Scale (SUS). Thirty-seven professionals participated, comprising 12 physiatrists, 14 ISPO Category I prosthetists/orthotists, and 11 ISPO Category III technicians, with a mean age of 39.5 years and nearly 60% having more than five years of professional experience. Overall, the use of CDSS led to improved accuracy, with median scores rising from 40% to 60%, and reduced decision time, which fell from 144 to

120 seconds, although these changes did not reach statistical significance. Subgroup analysis revealed that physiatrists showed greater gains in accuracy (40% to 70%) but required more time when using the system. By contrast, ISPO Category III technicians achieved stable accuracy while significantly reducing their decision time (133 to 99 seconds). ISPO Category I prosthetists/orthotists showed no meaningful differences across outcomes. The overall mean SUS score was 63.5, suggesting marginal usability, though less-experienced users rated the system more positively, with mean scores approaching 72. In this simulation, the CDSS did not yield statistically significant gains in accuracy or decision time. Nonetheless, with usability improvements, targeted training, and local adaptation, its decision-support value may increase. Adequately powered, real-world studies are needed to confirm clinical impact.

Keywords: Clinical decision support system; Prosthetic prescription; Lower limb amputation; Prosthesis

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INTRODUCTION

Clinical Decision Support Systems (CDSS) are computer-based tools designed to assist healthcare professionals in making more accurate and consistent decisions. By integrating evidence-based guidelines with patient-specific information, CDSS reduce cognitive workload, improve decision accuracy, and support

timely clinical management [1, 2]. These systems have become increasingly important in modern healthcare as the complexity of medical data and treatment options continues to grow [2].

In rehabilitation medicine, CDSS have been widely applied to support clinical reasoning and optimize patient care. Previous studies have reported the use of CDSS in various domains, such as providing exercise guidance in cardiac rehabilitation, recommending therapeutic exercise for patients with back pain, supporting decision-making in stroke rehabilitation, and analyzing gait patterns to assist in treatment planning [3-6].

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Evaluations of these systems have demonstrated benefits including improved adherence to clinical guidelines, reduced variability in clinical decisions, enhanced patient outcomes, and higher efficiency of care delivery [2]. As a result, CDSS are now considered valuable tools that complement professional expertise and are increasingly integrated into routine rehabilitation practice.

Despite the growing adoption of CDSS in rehabilitation, there is a notable absence of research and development in the area of prosthetic prescription for individuals with lower-limb amputation. Prosthetic prescription is a complex clinical task that requires consideration of multiple factors, including the level of amputation, residual limb characteristics, comorbidities, functional level, and patient goals [7]. Errors or inconsistencies in prescription may result in poor prosthetic fit, functional limitations, discomfort, or secondary complications such as skin breakdown and musculoskeletal pain [8]. Therefore, a decision support system tailored to prosthetic prescription could play a crucial role in improving care quality and patient outcomes.

The need for such a system is particularly pressing in Thailand. The country faces significant challenges in prosthetic and orthotic care due to rapid advancements in prosthetic technology, combined with a limited workforce of certified prosthetists and orthotists (International Society for Prosthetics and Orthotics [ISPO] Category I) [9]. This shortage often leads to variability in prescription quality, delayed service delivery, and suboptimal prosthetic outcomes. Patients may experience poor fitting, reduced mobility, and secondary health complications, all of which negatively impact rehabilitation potential and quality of life [10]. A CDSS specifically designed for lower-limb prosthetic prescription has the potential to mitigate these challenges by supporting clinicians in making evidence-based, standardized, and individualized prosthetic decisions.

Accordingly, the present study was undertaken to address this critical gap. The primary objective is to evaluate whether the use of a CDSS improves the appropriateness of prosthetic prescription decisions. Secondary objectives include assessing the impact of the CDSS on decision-making efficiency (time required to complete prescriptions) and on perceived usability.

Methods

Study Design

This study employed a prospective, simulation-based crossover trial to evaluate the CDSS. A crossover design was chosen to allow each participant to serve as their own control, thereby reducing between-subject variability and the influence of individual differences in baseline decision-making skills. In this trial, all participants will make prosthetic prescription decisions for two clinical case scenarios: one with CDSS support (intervention condition) and one without CDSS support (control condition).

The order of exposure will be randomized using a computer-based randomizer. Approximately half of the participants will use the CDSS for the first scenario and then complete the second scenario without it, while the other half will begin in the control condition before crossing over to the intervention condition. This randomization of scenario order and intervention is intended to minimize potential carryover effects.

Setting and Participants

The study will be conducted in an online setting using self-reported responses in September 2025. Participants will include healthcare professionals involved in amputee rehabilitation and prosthetic prescription, specifically (1) physiatrists, (2) prosthetists/orthotists, and (3) prosthetic/orthotic technicians. These professional groups are classified by the International Society of Prosthetics and Orthotics (ISPO) within Category I and Category III [11].

To be eligible, participants must have at least six months of experience in lower-limb amputee management. Individuals without any clinical exposure to prosthetics, or those unable to use a computer or mobile interface, will not be included in the study.

CDSS Development

The CDSS is a rule-based software prototype developed as a web application to assist clinicians in prescribing lower-limb prostheses. It was implemented using PHP version 7.4.33 with a PHP 8.3.24 development server and was designed to be automatically responsive for both personal computer and mobile device use.

Clinicians interact with the system by entering key patient data, including sex, age, level of amputation (transtibial, transfemoral, or knee disarticulation), stump length and shape, skin condition, comorbidities (such as diabetes mellitus or cardiac disease), estimated functional level (K-level), and history of falls.

The CDSS knowledge base integrates evidence-based guidelines and rule sets derived from literature [12 - 24]. Its algorithms apply stump length to guide socket selection, K-level to guide prosthetic knee selection (in transfemoral and knee disarticulation cases), and K-level to guide foot unit selection. For example, individuals classified as K3 are recommended to use dynamic energy-storing feet. In addition, the system provides alert notifications related to cardiac status, fall risk, and adverse skin conditions.

The graphic user interface was optimized to minimize the number of user interaction steps. Completing a prosthetic prescription required 28 clicks for transfemoral and knee disarticulation cases and 26 clicks for transtibial cases. The CDSS prototype web application is publicly accessible at http://www.procdss.site/prosthetic_clinic.

Study Procedure

Each participant will complete two standardized clinical case scenarios simulating patients who require a new prosthetic prescription. These vignettes, developed by the research team in consultation with senior prosthetists, encompass both transfemoral and transtibial amputation levels to represent a broad range of clinical presentations. For each scenario, participants will formulate a prosthetic component either with or without the support of the CDSS, depending on their assigned condition. Without prior CDSS training, participants completed the scenarios using only the interface for self-instruction.

To minimize recall bias, no participant will encounter the same case twice; instead, cases will be distributed so that each scenario is completed by an equal number of participants in both CDSS and non-CDSS conditions, enabling balanced comparisons.

The sequence of conditions (CDSS first vs. second) and the assignment of specific cases to each condition

will be randomized using a computer-generated allocation schedule as in figure 1. The time required to complete each scenario will be automatically recorded, beginning from the moment the program is opened until the final prescription decision is submitted. After completing both scenarios, participants will complete a post-study questionnaire that includes the System Usability Scale (SUS), a validated 10-item Likert scale yielding a composite usability score out of 100, to assess the usability of the CDSS.

Outcomes Measures

Primary Outcomes

Appropriateness of Prosthetic Prescription: For each clinical scenario, a senior prosthetist will assess whether each component is indicated for use, applying the same knowledge base and decision rules embedded in the CDSS prototype. Scoring is binary at the component level: 1 point for each correct (indicated) component and 0 otherwise. Transtibial cases comprise five components—socket, liner, suspension, auxiliary suspension, and foot unit (maximum score = 5). Transfemoral cases comprise six components—the same five plus a knee unit (maximum score = 6). Total scores will be converted to percentages and compared between CDSS-assisted and non-assisted conditions.

Secondary outcomes

Decision-Making Efficiency: Efficiency will be measured as the time required to complete each prescription decision (recorded in seconds). The median completion time will be calculated and compared between CDSS-assisted and non-assisted conditions.

System Usability Scale (SUS): The SUS is a validated 10-item Likert scale instrument used to assess the perceived usability of software systems. Each item is rated on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). Item scores are converted into composite scores ranging from 0 to 100, with higher scores indicating better usability. A score of 68 is generally regarded as the benchmark for acceptable usability. Scores above this threshold indicate

above-average usability, while scores exceeding 80 reflect excellent usability and strong user acceptance.

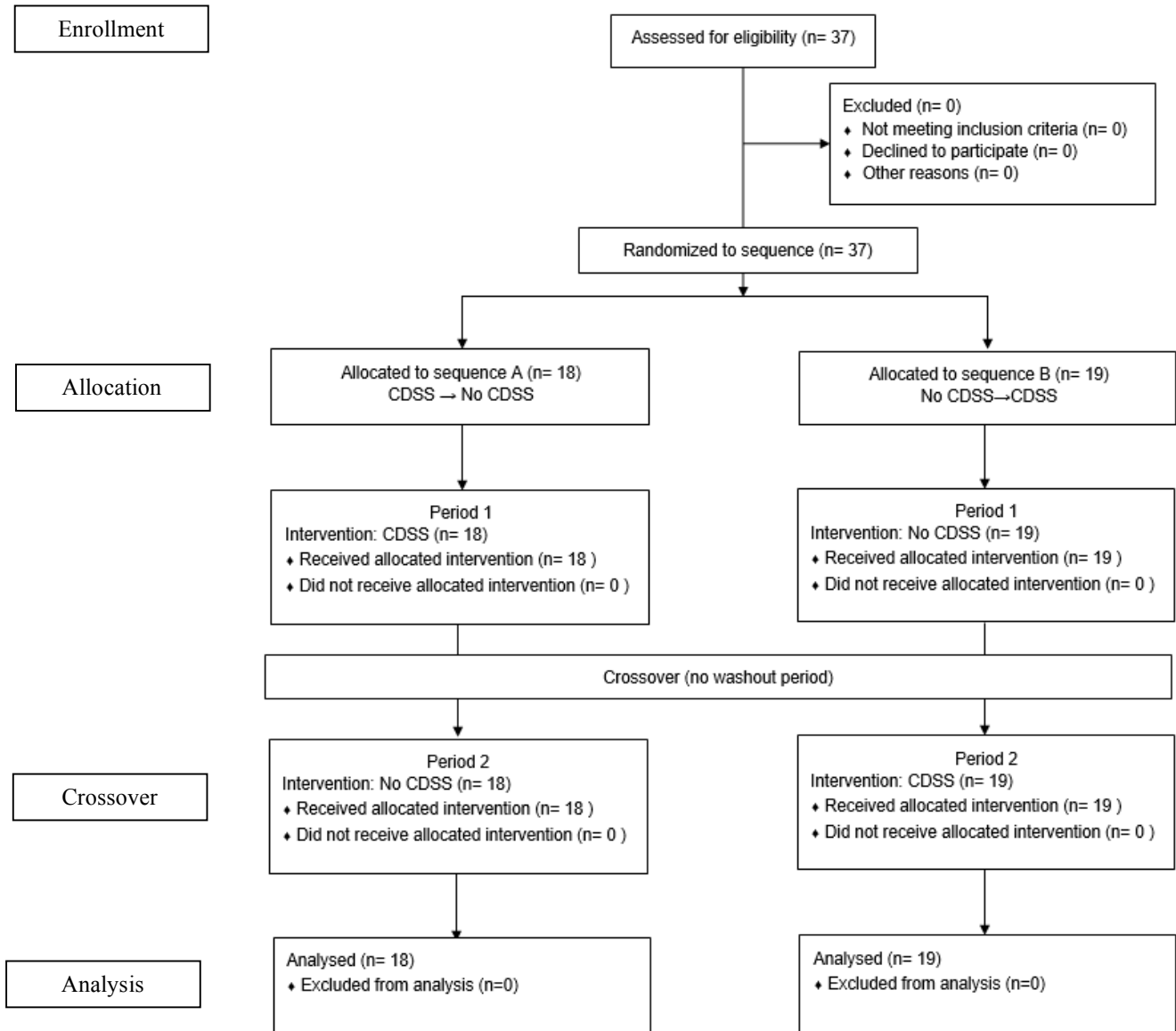


Fig. 1 CONSORT flow diagram

In contrast, scores below 68 suggest that substantial improvements are required in the system's design or interface. [25]. A Thai version of the SUS, previously translated and validated, was employed in this study [26].

Sample Size Calculation

The primary outcome of this study is decision accuracy when prescribing lower-limb prosthetic components with versus without the CDSS. The study was designed as a within-subject crossover trial, and sample size estimation was therefore based on the paired t-test framework. Assuming a moderate effect size (Cohen's $d = 0.5$), a two-sided $\alpha = 0.05$, and

80% statistical power, the required minimum number of participants was 32. To allow for potential non-completion or missing data, the target recruitment was increased to 35 participants. With this sample, the study retains adequate power to detect a clinically meaningful improvement in prescription accuracy attributable to the CDSS.

Statistical Analysis

Data will be analyzed with SPSS version 27 (IBM Corp., Armonk, NY, USA). Descriptive statistics will summarize participants' baseline characteristics. For baseline between-group comparisons, distributional

assumptions will be assessed normality. When assumptions are met, one-way ANOVA will be used for continuous variables; otherwise, the Kruskal–Wallis test with Dunn–Bonferroni post hoc comparisons will be applied. For paired primary and secondary outcomes, normality will be evaluated on the within-participant difference. Given anticipated non-normality and bounded percentage scales, the Wilcoxon signed-rank test is prespecified as the primary analysis; where differences are approximately normal, paired t-test results (mean difference and 95% CI) will be reported as a sensitivity analysis. Categorical variables will be compared using Fisher's exact test. System Usability Scale (SUS) scores will be summarized descriptively and interpreted against established benchmarks. A two-sided p-value < 0.05 will be considered statistically significant.

All additional endpoints and subgroup analyses were treated as exploratory. Given the pilot design and small subgroup sizes, no formal multiplicity adjustment was applied to avoid loss of power and inflation of type II error; p-values for secondary and subgroup comparisons are reported unadjusted and interpreted cautiously, with emphasis on effect sizes and 95% confidence intervals. For Wilcoxon signed-rank tests, effects are summarized on the original scale as the Hodges–Lehmann median paired difference (computed as No CDSS - CDSS) with 95% CI, and as a standardized measure using the rank-biserial correlation (r).

Result

A total of 37 participants were included in this study (22 males, 15 females) with a mean age of 39.5 years (SD = 10.7). When divided by professional group, 12 physiatrists (32.4%), 14 prosthetists/orthotists (37.8%), and 11 prosthetic/orthotic technicians (29.7%) were recruited. Considering their experience, 59.5% of participants had more than 5 years of experience. Between-group comparisons indicated statistically significant differences in professional role and years of experience, whereas no significant difference was observed for age (Table 1).

Overall, median accuracy was 40% without CDSS and 60% with CDSS, with no statistically significant difference (Wilcoxon $p = 0.855$). Median decision time decreased from 144 s to 120 s with CDSS (HL median difference = -20 s, 95% CI -46 to 8.5), which was not significant ($p = 0.107$).

By subgroup, physiatrists showed higher median accuracy with CDSS (40%→70%) but longer decision time (115 s → 173.5 s); neither comparison was significant ($p = 0.356$ and $p = 0.959$, respectively). Prosthetic/orthotic technicians showed no significant difference in accuracy (40% vs 40%, $p = 0.431$) but a significantly shorter decision time with CDSS (133 s→99 s; HL = -35 s, 95% CI -125 to -8; $p = 0.021$). Among ISPO Category I prosthetists/orthotists, accuracy did not differ (60% vs 60%, $p = 0.943$) and the reduction in decision time (167 s→134.5 s) was not significant (HL = -16.5 s, 95% CI -87 to 67; $p = 0.333$). Results stratified by tenure (≤ 5 years vs >5 years) were also non-significant for both accuracy ($p = 0.722$ and $p = 0.977$) and decision time (HL = -15 s, 95% CI -67.5 to 28; $p = 0.480$ and HL = -22 s, 95% CI -61 to 35; $p = 0.113$) (Table 2).

The mean SUS score for all participants was 63.51 (SD = 16.2), which is considered indicative of marginal usability or a need for improvement. Among participants with less than 5 years of experience, the mean SUS score was 71.88 (SD = 20), representing the highest mean score among all subgroups and falling within the range of good usability (acceptable and above average) (Table 2).

Discussion

This prospective, simulation-based crossover trial evaluated the accuracy and time efficiency of a CDSS for lower-limb prosthetic prescription among healthcare professionals involved in amputee rehabilitation. The overall results demonstrated an improvement in accuracy from 40% without CDSS to 60% with CDSS; however, this difference was not statistically significant. Additionally, the median decision time decreased by 24 seconds with CDSS use, but this reduction also failed to reach statistical significance.

Additional insights were noted in the subgroup of physiatrists, who demonstrated a marked improvement in accuracy scores, reaching 75% compared with the traditional method. This improvement, however, was accompanied by a prolonged median decision time, and neither outcome achieved statistical significance. One possible explanation is that physiatrists, with a broader but less frequent exposure to prosthetic prescription compared with prosthetists, may benefit more from the structured guidance provided by CDSS, but require additional time to navigate the system and integrate its recommendations into their decision-making process [27],[28].

In contrast, prosthetic/orthotic technicians (ISPO Category III) showed a significant reduction in decision time while maintaining consistent accuracy. This may reflect their reliance on procedural knowledge rather than advanced clinical reasoning, allowing the CDSS to streamline routine decision steps and thereby improve efficiency [2]. These findings suggest that CDSS use may enhance workflow efficiency among less specialized users, while its effect on decision accuracy may depend on the user's baseline expertise and familiarity with prosthetic prescription.

No significant improvements were observed among prosthetists/orthotists (ISPO Category I) or in analyses stratified by professional experience. This may be explained by their already high level of expertise, which relies heavily on well-honed intuitive reasoning [29]. As a result, these professionals may derive limited

additional benefit from decision support within their domain of mastery, leading to minimal observable changes in either accuracy or efficiency.

The overall accuracy across all professional subgroups was relatively low, suggesting systemic challenges in prosthetic prescription beyond individual expertise. Several factors may account for this finding. First, the scoring rubric may have been overly stringent, as clinically acceptable but non-identical solutions were sometimes categorized as inaccurate, thereby lowering the observed accuracy. Second, the complexity of the simulated cases and the limited clinical details provided may have hindered optimal decision-making, particularly for borderline scenarios. Third, the absence of a unified, context-specific guideline in Thailand may contribute to heterogeneous practices and uncertainty in prosthetic component selection. These observations highlight the need for strengthening educational curricula, particularly through competency-based modules and interprofessional training that emphasize structured decision-making in prosthetic prescription. In addition, continuing professional development activities and national-level guideline development are warranted to ensure consistency, align practice with evidence-based standards, and support clinicians across disciplines. CDSS integration may further serve as a tool to bridge knowledge gaps; however, its design should be refined to enhance transparency, reduce cognitive load, and better reflect localized clinical practice.

TABLE I. BASELINE CHARACTERISTICS OF PARTICIPANTS

Variable		Prosthetic/ orthotic technicians (n=11)	Prosthetists/ orthotists (n= 14)	Physiatrists (n=12)	Total (n = 37)	p - value
Age, years (mean $\pm$ SD)		39.9 $\pm$ 11	42.8 $\pm$ 9.4	35.2 $\pm$ 12.0	39.5 $\pm$ 10.7	0.196
Sex	Male, n (%)	11 (100)	9 (64.3)	4 (33.3)	22 (64.9)	0.003
	Female, n (%)	0 (0)	5 (35.7)	8 (66.7)	13 (35.1)	
Experience	$\leq$ 5 years	6 (54.5)	1 (7.1)	8 (66.7)	15 (40.5)	0.003
	>5 years	5 (45.5)	13 (92.9)	4 (33.3)	22 (59.5)	

TABLE II. COMPARISON OF PRESCRIPTION OUTCOMES WITH AND WITHOUT CDSS

Group		Median accuracy percentage (IQR)					Median decision time (sec) (IQR)				
		CDSS	No CDSS	HL median difference (95% CI)	p-value	r	CDSS	No CDSS	HL median difference (95% CI)	p-value	r
Role	Prosthetic/ orthotic technicians	40 (60)	40 (40)	-10 (-40, 20)	0.431	-0.26	99 (68.5)	133 (118)	-35 (-125, -8)	0.021	-0.77
	Prosthetists/ orthotists	60 (60)	60 (45)	0 (-30, 30)	0.943	0.02	134.5 (167)	167 (124.3)	-16.5 (-87, 67)	0.333	-0.31
	Physiatrist	70 (60)	40 (80)	20 (-20, 50)	0.356	0.29	173.5 (217.8)	115 (218.5)	-1 (-89.5, 60)	0.959	-0.016
Years of experience	≤5	70 (55)	60 (40)	10 (-20, 40)	0.722	0.10	153 (72.5)	133 (166.3)	-15 (-67.5, 28)	0.480	-0.20
	>5	40 (50)	40 (40)	0 (-20, 20)	0.977	-0.007	102 (183.5)	155 (137)	-22 (-61, 35)	0.113	-0.39
Overall		60 (60)	40 (50)	0 (-10, 20)	0.855	0.034	120 (132.5)	144 (156.5)	-20 (-46, 8.5)	0.107	-0.30

* HL = Hodges–Lehmann median of paired differences computed as (CDSS – No CDSS)

Although the overall SUS score fell within the range of marginal usability, indicating a need for improvement, subgroup analysis provided additional insights. Participants with less professional experience and physiatrists achieved the highest and second-highest scores, respectively. This may be explained by their younger age, more recent graduation, and consequently greater technological literacy and openness to adopting new technology [30]. In contrast, lower scores among other groups may reflect reduced technological familiarity, particularly among older participants. These findings underscore the importance of refining the CDSS interface to ensure ease of use across all age groups and levels of technological literacy. Incorporating a user-centered design approach—with iterative usability testing across different professional backgrounds, age groups, and levels of digital experience—may help optimize the interface, reduce cognitive burden, and enhance acceptance of the system in routine clinical practice.

This work advances the field by demonstrating a structured approach to developing and appraising a guideline-based CDSS for prosthetic prescription, articulating a reusable evaluation framework (accuracy, efficiency, usability), and highlighting design and implementation considerations that influence performance across user groups. The effort emphasizes localization of guidance, workflow compatibility, and targeted

training as prerequisites for effective deployment. The resulting artifacts—decision logic, evaluation metrics, and standardized case materials—offer practical value for education, service quality assurance, and future research. Collectively, these contributions provide a foundation for iterative refinement and for adequately powered, real-world studies aimed at achieving consistent, evidence-based prosthetic care, while underscoring that the system is a proof-of-concept requiring rigorous, adequately powered real-world validation to establish safety, effectiveness, and patient impact.

This study has several limitations that warrant consideration. First, the testing of CDSS versus non-CDSS conditions relied on user self-report rather than a fully controlled environment. This approach may have introduced variability in how participants completed the tasks, with potential errors arising from differences in environment, concentration, unstable internet connections or differences in testing conditions. Moreover, participants did not receive formal training on the use of the CDSS or its underlying algorithm, which may have biased the results. Future studies should incorporate structured training materials and employ standardized testing environments to minimize these sources of error.

Second, the CDSS algorithm was adapted from international evidence and prior studies but did not incorporate data or validation from Thailand. As there are currently no published studies on lower-limb prosthetic prescription in the Thai context, the system's recommendations may not fully align with local clinical practice patterns or resource availability. This underscores an important research gap in Thailand, where foundational studies are needed to establish evidence-based practice in prosthetic prescription. Development of a Thailand-specific guideline is therefore essential for future iterations of the CDSS to ensure contextual relevance and clinical applicability.

Third, the relatively small sample size may limit the generalizability of the findings and introduce sampling bias. Larger multicenter studies are needed to validate these results and strengthen the evidence base. Fourth, this study did not include amputee patient outcomes, which are necessary to fully evaluate the clinical effectiveness of the CDSS. Future research should incorporate patient-centered outcomes and explore implementation in real-world clinical practice.

Future directions include further development of the CDSS with customization according to the resources and prosthetic components available in each hospital, particularly in low- and middle-income country (LMIC) settings such as Thailand, where high-cost components commonly used in high-income countries are not widely accessible. Tailoring the CDSS to reflect local material availability and reimbursement policies would enhance its practicality and adoption. In addition, transitioning from a purely rule-based system toward an artificial intelligence-driven approach holds promise, as such systems could continuously learn and improve their accuracy and precision in predicting appropriate prosthetic components.

Conclusion

In this simulation study, CDSS use did not produce statistically significant improvements in component-level accuracy or decision time, and overall usability was marginal. Observed subgroup patterns are exploratory and require confirmation in adequately powered,

real-world evaluations. Priorities for subsequent iterations include usability refinement, workflow integration, localized content, and structured user training; these should be evaluated prospectively to determine whether an optimized CDSS improves prescribing efficiency.

Conflicts of interest declaration

The authors confirm that there is no conflict of interest related to the manuscript.

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Generative AI Declaration

Generative artificial intelligence (AI) tools, specifically ChatGPT (GPT-5, OpenAI, San Francisco, CA, USA; accessed September 2025), were used solely to assist with language editing of the manuscript. All content was carefully reviewed, revised, and verified by the authors, who assume full responsibility for the integrity and accuracy of the final work.

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