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REVIEW

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"New technologies applied in self-care to patients with diabetic foot ulcers: a scoping review"

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Abstract

Background The integration of new technologies has shown potential to enhance self-care practices among patients with diabetic foot ulcers (DFUs). Understanding the effectiveness of these interventions can inform clinical and public health strategies to prevent complications and improve patient outcomes.

Objectives This scoping review aims to assess the impact of digital and educational technologies on self-care practices and health outcomes in individuals with diabetic foot ulcers.

Sources of evidence Databases searched encompassed EMBASE, MEDLINE, SciELO, WoS, Scopus, and PubMed, covering publications up to September 2024. The search strategy incorporated MeSH terms and keywords related to "self-care," "diabetic foot ulcers," and "educational technology."

Methods After duplicate removal, titles and abstracts were screened independently by three reviewers. Full texts of selected articles were analyzed, and data regarding study design, interventions, outcomes, and populations were extracted using standardized forms. Discrepancies were resolved by consensus.

Results From 442 identified records, 12 studies met inclusion criteria, primarily highlighting the role of mobile applications and digital educational tools in enhancing self-care behaviors, adherence, and complication prevention. Positive effects on patient knowledge and routine adherence were frequently reported.

Conclusions Technological interventions show promise in improving self-care among DFU patients; however, further high-quality, longitudinal studies are needed to establish best practices and long-term benefits.

Keywords Self-Care, Diabetic foot ulcers, Educational technology

MeSH Terms: "Self Care"[Mesh]; "Diabetes Mellitus"[Mesh]; "Diabetic Foot"[Mesh]; "Foot Disease"[Mesh]; "Educational Technology"[Mesh]; "Diabetic Angiopathies"[Mesh]

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Introduction

Diabetes mellitus is a public health problem that affects 415 million people aged 20–79 years and is predicted to increase to 642 million by 2040 [1]. It is estimated that 2% of the burden of the disease is attributable to a high Body Mass Index, and the predicted rise is due to obesity [2]. Patients with diabetes have a higher risk of developing cardiovascular diseases, leading to infarction, stroke, nephropathy, neuropathy, and retinopathy [3, 4]. Among the numerous complications associated with diabetes, diabetic foot ulcer stands out as a particularly concerning issue. This serious condition, which is often preventable, can lead to debilitating consequences, including high rates of amputation, hospitalization, and long-term disability. These conditions increase medical costs.

Diabetic foot ulcers (DFUs) are among the most common and preventable complications. The lifetime incidence of DFUs is notably high worldwide, ranging from 19 to 34%. The post-diagnosis survival rates were approximately 86.9% at one year, 66.9% at three years, and 50.9% at five years [5]. The recurrence rate is estimated to be approximately 22.1% per person-year [6]. DFUs are a leading cause of global amputation, hospitalization, disability, and reduced quality of life, accounting for approximately 2% of the global disease burden [7]. This severe complication, characterized by lesions in the skin and underlying tissues of the foot, is largely preventable, but remains a significant contributor to morbidity, healthcare costs, and disability worldwide.

Traditional approaches to diabetic foot ulcer care often fall short of effectively engaging patients in their own health management. The emergence of innovative digital health technologies offers new avenues for improving self-care practices.

The use of diabetes technologies has increased in North America and European countries over the past 10 years [8]. These technologies, encompassing wearable sensors, mobile health applications, and telemedicine platforms, empower patients to take a more proactive role in managing their condition. For instance, continuous glucose monitoring systems and smart footwear equipped with pressure sensors provide real-time data, enabling early detection of potential problems. Mobile health apps offer educational resources, personalized reminders, and direct communication channels with healthcare providers, thus facilitating timely intervention [9].

Recent technologies and their effectiveness

In recent years, various technologies, including mobile applications, wearable sensors, and telemedicine platforms, have been developed to enhance adherence to self-care practices and facilitate the early detection of complications. Evidence indicates that these tools improve patients' knowledge and reduce the incidence of new lesions.

Self-care is essential for preventing and managing complications of diabetic foot ulcers [10]. Innovative technologies such as sensors and portable devices have significantly improved medical monitoring by offering continuous observation and real-time support. These devices allow for the control of foot temperature, glucose levels, and plantar pressure, facilitating remote treatment and reducing the need for in-person consultation [7]. The integration of artificial intelligence and digital communication provides personalized and timely management of foot ulcer. Advances in these areas have empowered patients to engage in self-care and offer innovative solutions to prevent complications [11].

The emergence of mobile health technologies ([12, 13]), presents a promising avenue for enhancing self-care practices among patients with chronic conditions, including diabetes. Their study categorized mobile applications based on their purpose, such as providing information on nutrition and diet, facilitating the measurement of physiological parameters, offering medication reminders, and underscoring their potential to improve patient engagement and adherence to treatment plans.

Throughout this review, the term "diabetic foot ulcer" (DFU) is used as a broader construct encompassing foot complications arising from diabetes. However, the more clinically specific term "diabetic foot ulcer" (DFU) is widely adopted in the literature and is often the primary focus of digital interventions aimed at improving self-care and preventing complications. For clarity and alignment with the standard terminology, DFU will be used when referring specifically to ulcerative complications.

According to the IWGDF 2023 definition, a diabetic foot ulcer (DFU) is a full-thickness wound located below the ankle in a person with diabetes, often resulting from neuropathy and peripheral arterial disease. DFUs affect 6.3% of the global diabetic population annually and are the leading cause of non-traumatic lower extremity amputations. Global challenges in self-care include a lack of awareness, poor access to healthcare education, and disparities in the adoption of preventive practices. Recent innovations, such as AI integrated insoles, sensor-based wearables, and smartphone-based education, offer scalable and cost-effective strategies. We opted for a scoping review to systematically map and categorize this rapidly evolving field of foot ulcers, which lacks standardization and requires broader synthesis before conducting meta-analyses.

Standard practices and global challenges

Globally, inadequate self-care, insufficient education regarding preventive measures, and limited resources in underserved areas contribute to the high rates of complications. These include increased amputation and elevated morbidity and mortality rates associated with diabetic foot ulcers.

Because of the recent incorporation of these technologies and the high global burden of diabetic foot ulcer disease, this study aimed to determine the effectiveness of new educational technologies in the prevention and self-care of patients with diabetic foot ulcer [14].

Justification for the scoping review

A scoping review was conducted to map the existing technological interventions, assess their scope, and briefly describe their impact. This methodology allows for the identification of gaps in the current evidence and the exploration of the diversity of approaches available in this rapidly evolving field.

Objectives

This scoping review will assess the effectiveness of new technologies in improving self-care practices and health outcomes among patients with foot ulcer by assessing the impact of various technological interventions, such as mobile applications, educational software, and other digital tools, on patient knowledge, adherence to self-care regimens, and the prevention or mitigation of complications.

Material and method

This manuscript was prepared in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses **extension for Scoping Reviews Checklist**). The study protocol was registered in PROSPERO (ID: CRD42023391447).

Study Design: This manuscript was written in accordance with the PRISMA-ScR guidelines [15].

Data Sources: A comprehensive search was performed using multiple databases, including EMBASE, MEDLINE, LILACS, SciELO, Web of Science (WoS), Scopus, and PubMed, up to September 2024. No restrictions were applied based on language or geographic location.

Search Criteria and Eligibility Conditions: The analysis was structured around the PECO framework, considering the following elements: population (P), Exposure or Intervention (E), comparator (C), and outcomes (O). The focus was on studies related to Diabetic Foot Ulcers (P) that examined the impact of Educational Technology (E) on self-care practices (O) without necessarily including a comparator group (C). This framework guided the systematic selection and evaluation of the relevant research. Additionally, a manual search complemented by cross-referencing was conducted to ensure a comprehensive coverage of the literature (see Table 1 for search strategies corresponding to the sources used).

Eligibility criteria

Population

The review included studies involving adult patients (aged 18 years and older) diagnosed with either type 1 or type 2 diabetes mellitus who are at risk for or currently experiencing diabetic foot ulcer complications. Studies focusing on specific patient subgroups, such as individuals with neuropathy or peripheral artery disease, were also eligible. There were no language restrictions on the included studies.

Intervention

Studies involving technological interventions aimed at enhancing self-care and management of foot ulcers are included. This encompasses mobile applications, wearable sensors, telehealth platforms, digital educational

Table 1 Search strategies according to the source of information used. (*N* = 844)

Source of information	Search strategy	ARTICLES
EMBASE	('diabetes mellitus'/exp OR 'diabetic complication'/exp OR 'diabetic foot'/exp OR 'foot disease'/exp OR 'diabetic angiopathy'/exp) AND ('self care'/exp OR 'educational technology'/exp OR 'amputation'/exp OR 'technology edu' OR 'self-care software'/exp OR 'mobile health technology'/exp OR 'mobile application'/exp OR 'education'/exp) AND 'educational technology'/exp AND ('clinical study'/exp OR 'case report'/exp OR 'cohort analysis'/exp OR 'systematic review'/exp OR 'controlled study'/exp OR 'health care quality'/exp)	36
MEDLINE	(diabetes) AND (educational diabetes OR prevention OR screen) AND mobile OR new technology OR educational intervention diabetes) AND (foot ulcer OR foot diabetes selfcare OR self care OR educational technology)	197
SciELO	pie diabético AND autocuidado AND tecnología	7
PUBMED	"Self Care"[Mesh] OR "self care"[Title/Abstract] OR "prevention" [Title/Abstract] OR "Amputation, Surgical"[Mesh] OR "amputation"[Title/Abstract] AND "Diabetes Mellitus"[Mesh] OR "diabetes mellitus"[Title/Abstract] AND "Educational Technology"[Mesh] OR "technology educa*"[Title/Abstract]	546
SCOPUS	(TITLE-ABS-KEY ("Self Care") OR TITLE-ABS-KEY ("self care") OR TITLE-ABS-KEY ("prevention") OR TITLE-ABS-KEY ("amputation")) AND (TITLE-ABS-KEY ("Diabetes Mellitus") OR TITLE-ABS-KEY ("diabetes mellitus")) AND (TITLE-ABS-KEY ("Educational Technology") OR TITLE-ABS-KEY ("technology educa*"))	35
WoS	("Self Care" OR "self care" OR "prevention" OR "Amputation, Surgical" OR "amputation") AND TS=("Diabetes Mellitus" OR "diabetes mellitus") AND TS=("Educational Technology" OR "technology educa*")	12
LILACS	"pie diabético" AND Autocuidado AND tecnología	11

resources, and other digital health tools designed to improve patient education, adherence to self-care routines, facilitate the early detection of complications, and support overall disease management.

Comparator

The review primarily considered studies without a control or comparator group; however, where applicable, studies with comparative analyses of interventions are acknowledged.

Outcomes

The key outcomes assessed included patient engagement in self-care practices, adherence to treatment protocols, early detection of ulcer-related complications, improvements in patient knowledge, and overall influence of digital health interventions on ulcer recurrence and disease progression.

Study selection Duplicate entries identified across various information sources were eliminated. The remaining documents were assessed by title and abstract based on the established eligibility criteria. Three seasoned reviewers (EA, MFG, and NGM) performed a complete analysis of the selected articles. Differences were settled through consensus.

Data collection process: Three researchers thoroughly reviewed each chosen article, extracted pertinent data, and confirmed its accuracy using the Covidence software. The gathered data were organized in a Microsoft Excel spreadsheet (version 23.10).

Participants

This scoping review will encompass studies involving adult patients (18 years or older) diagnosed with diabetes (type 1 or type 2) who are at risk for or experience diabetic foot ulcer complications. Studies that focus on specific patient subgroups with foot ulcer, such as those with neuropathy or peripheral artery disease, will also be included. There were no restrictions on the language of the studies for inclusion.

Settings: This scoping review will take into account studies performed in any environment (e.g., hospitals, clinics, community centers, home-based) where new technologies are utilized for diabetic foot ulcer self-care. There are no limitations based on geographical location.

Main Outcome Measures: This study aimed to evaluate the influence of technology on self-care practices among individuals with diabetes. The outcomes were categorized into four key areas.

- Technology Impact & Usage: This study examined how technology enhances self-care practices, including engagement with mobile technology, the positive effects of various technological interventions, and their cost-effectiveness.
- Adherence and Behavior Change: This section focuses on improving adherence to self-care practices through technology. It encompasses the use of digital tools, reminders, personalized self-care plans, and feedback from technological interventions that encourage behavioral change.
- Complication Prevention and Management: Here, we assessed the role of technology in preventing complications associated with diabetes. This includes evaluating its effectiveness in self-monitoring, addressing issues such as neuropathy, and exploring the challenges of customizing solutions to individual needs.
- Educational Technology: This category investigates the application of educational technology interventions, including online platforms, wearable devices, and various educational resources. The specific metrics for each outcome are detailed in the Data Analysis section.

Summary Measures: No statistical tools were employed in this scoping review.

Risk of bias in individual studies: Owing to the exploratory nature of this study, a formal assessment of the risk of bias was not performed. However, methodological quality considerations were taken into account during the study selection process in accordance with recommendations for rapid reviews.

Results

The selection process for the studies involved an initial search, which resulted in 844 records across various databases. After removing duplicates, 442 records were subjected to title and abstract screenings. Of these, 402 records did not meet the predefined eligibility criteria and were excluded. A full-text review of the remaining 14 articles led to the exclusion of an additional 4 studies, while one more was identified through alternative methods. This process culminated in the final cohort of 12 studies included in this scoping review.

This review analyzed 12 studies that examined various technological interventions aimed at improving self-care in patients with foot ulcers. Interventions ranged from mobile applications and educational videos to telehealth platforms and wearable sensors. A summary of the included studies is shown in Table 2. Summary of study characteristics and key findings from the Scoping Review, highlighting the authors, publication years, methodologies, and characteristics of the patient populations involved. Table 3. Originally included studies ($N = 12$) (Table 4). Year of publication of the included studies:

Table 2 Summary of study characteristics and key findings from the scoping review

Author, Year and Country	Title	Language	Disease	Educational Technology Implemented in the Study	Variables Reported for Foot Self-Care	Development Phase of the Mobile Application	Range Age	Participants	Metodology	Financial Support
Gois Lopes et al. (2024) Brazil	Needs and preferences regarding a mobile application to support diabetic foot self-care	English /Portuguese	T2DM	Mobile application designed to support foot self-care	Informational needs, essential functionalities required for foot health self-care. The user experience variable was also reported, highlighting the importance of customizability and flexibility in the application	Developmental phase	42 to 76 years	16	Qualitative, exploratory-descriptive study involved semi-structured interviews	No declared
Barbosa Marques et al. (2023) Brazil	Mobile Application for Adhering to Diabetic Foot Self-care: Randomized Controlled Clinical Trial	English /Portuguese	T2DM	Mobile health (mHealth) technologies like the PedCare app	Frequency of Foot Care Assessments	Validation and testing	Older than 18 years	42	Randomized Controlled Clinical Trial	None of the contexts reference financial support
Ferreira et al. (2023) Portugal	Educational Interventions on Diabetic Foot Self-Care: A Study Protocol for a Pragmatic Randomized Controlled Trial	English	Diabetes Mellitus	Videos or reading brochures in real time	Key self-care tools for diabetic foot management include an educational video created by doctors and nurses, and a brochure containing essential foot care information. The brochure features clear text and illustrations to guide self-care behaviors effectively.	Implementation and piloting phase	Aged 18 years or older	54	Randomized Controlled Trial	Foundation for Science and Technology (FCT) through the Portuguese State Budget and by a PhD fellowship from FCT.

Table 2 (continued)

Author, Year and Country	Title	Language	Disease	Educational Technology Implemented in the Study	Variables Reported for Foot Self-Care	Development Phase of the Mobile Application	Range Age	Participants	Metodology	Financial Support
Firdaus et al. (2023) Malaysia	The effect of mHealth program on behavior modification and health outcomes among patients with diabetes: A randomized controlled trial study	English	Type 2 diabetes mellitus (T2DM)	Mobile health (mHealth) application called: Diabetic Care App	Self-care for diabetic foot was assessed using the foot care section of the SDSCA questionnaire, which was designed to assess key behaviours such as daily foot inspection, hygiene practices and appropriate footwear use.	The "Diabetic Care App", appears to be in a late stage of development. It had already undergone content validation by experts and was used in a RCT	18 to 65 years	58 completed the program by the end of the five-week intervention period	Randomized controlled trial	Higher Education Research Promotion and Thailand's Education Hub for the Southern region of ASEAN Countries Project Office of the Higher Education Commission.
Kılıç and Karadağ (2023) Turkey	Mobile Application for Remote Patient Education and Follow-up for the Prevention of Diabetic Foot: M-DAKBAS	English	T2DM	Mobile application, m-DAKBAS	The m-DAKBAS app focuses on increasing users' confidence in managing their foot health, educating them on proper foot care, enabling blood glucose monitoring and encouraging regular foot self-examinations to detect problems early.	The m-DAKBAS mobile application has completed its development process and undergone a pilot study.	That information is not available from the paper.	88 participants, divided into two groups: 44 in the experimental group and 44 in the control group.	Randomized controlled pilot study	Funded by KOÇ University, Vehbi Koç Foundation
Haycocks et al. (2022) United Kingdom	Implementation of a novel mHealth application for the management of people with diabetes and recently healed foot ulceration: A feasibility study	English	T2DM, T1DM	Mobile health (mHealth) application called INTELLIN®	Key self-care practices include daily foot inspections to detect changes or issues, and the recording of foot health changes within the app. The INTELLIN® platform provides users with daily foot care advice and guidance for the management of diabetes-related complications.	Feasibility study	Ranged in age from 34 to 73 years old	24 patients were included in the final analysis	Pilot study	Innovate UK, as part of a Small Business Research Initiative Healthcare competition

Table 2 (continued)

Author, Year and Country	Title	Language	Disease	Educational Technology Implemented in the Study	Variables Reported for Foot Self-Care	Development Phase of the Mobile Application	Range Age	Participants	Metodology	Financial Support
Menezes et al. (2022) Brazil	Production and validation of the short film Pés que te quero®: educational technology for people with diabetes	English	T2DM, T1DM	Short film titled "Pés que te quero®	Self-care in diabetic foot management includes regular foot examination, maintaining good hygiene, choosing appropriate footwear and seeking timely medical attention for foot problems.	Development and validation of a short film	Older than 18 years	15 individuals diagnosed with diabetes	Validation Study	Funded by the Brazilian National Council for Scientific and Technological Development (CNPq)
Marques et al. (2020) Brazil	PEDCARE: validation of a mobile application on diabetic foot self-care	English /Portuguese	Diabetes Mellitus	Multimedia mobile application called PedCare	The folder highlights essential self-care practices to prevent diabetic foot complications, including daily foot checks, maintaining hygiene, staying hydrated, practicing proper nail care and using appropriate footwear.	Post-development validation phase	Aged 18 years or older	15 individuals with diabetes (the target audience)	Developing and validating the app itself	Funded by the Coordination for the Improvement of Higher Education Personnel.
Ferreira et al. (2019) Brazil	Rehabilitation technology for self-care: Customised foot and ankle exercise software for people with diabetes	English/ Portuguese	T2DM, T1DM	Web-based software application designed for foot and ankle exercises, accessible via computer or smartphone. (www.usp.br/labimph/s)	Self-care in diabetic foot management focuses on regular foot examination, proper hygiene, appropriate footwear selection and timely medical consultation. These practices are essential to prevent complications.	Development and validation of web software	18 years old or older	20 (diabetes specialists (n = 9) and users with diabetes (n = 20))	A pilot study was conducted to evaluate the software's usability and feasibility. Qualitative research (expert content validation) and quantitative research (user experience ratings, satisfaction scores)	CAPES, CNPq and FAPESP agency.

Table 2 (continued)

Author, Year and Country	Title	Language	Disease	Educational Technology Implemented in the Study	Variables Reported for Foot Self-Care	Development Phase of the Mobile Application	Range Age	Participants	Metodology	Financial Support
Galdino et al. (2019) Brazil	Validation of a booklet on self-care with the diabetic foot	English/ Portuguese	T2DM	Educational technology used in the study is a booklet designed to provide information and guidance on self-care for individuals with diabetic foot problems	The booklet is designed to empower people with diabetes to actively manage their foot health and prevent complications. It is based on the Self-Care with Diabetic Patient Feet Questionnaire and includes updated references on diabetes and diabetic foot care.	Post-validation phase	Aged 18 years or older	30	Development and validation of educational materials	None of the contexts reference financial support
Lavery et al. (2004) United States	Home Monitoring of Foot Skin Temperatures to Prevent Ulceration	English	T2DM	The study utilized home monitoring of foot skin temperatures.	Daily foot skin temperature monitoring, Adherence to a self-care protocol: Patients were taught a specific protocol to follow if they detected elevated foot temperatures (defined as a 2.2°C increase). Communication with healthcare providers.	The study focuses on home monitoring of foot skin temperatures using skin thermometers and doesn't describe the development of a mobile application.	The ages ranged from 40 to 80 years.	85	The study was a prospective, randomized, controlled trial	This study (1R43D K54559-01) was funded by the NationalInstitutes of Health/ National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)
Lavery et al. (2007) United States	Preventing Diabetic Foot Ulcer Recurrence in High-Risk Patients: Use of temperature monitoring as a self-assessment tool	English	T2DM	The study utilized a videotape as part of the education program. This videotape addressed the etiology of diabetic foot ulcers, risk factors, self-care practices, and early warning signs of diabetic foot disease	Self-care variables focused on participants' adherence to using a temperature monitoring device, their ability to identify areas of concern, and their engagement in foot health self-care practices.	Implementation phase	Age between 18 and 80 years	The study included a total of 173 individuals who were at high risk for diabetic foot ulceration	Protocol Randomized controlled trial design	The provided contexts do not specify the funding sources for the study.

Table 3 Origen included studies ($N=12$)

Study origen	No. Studies	%
Portugal	1	8.3
Brazil	7	58.3
Turkey	1	8.3
United States	2	16.7
Malaysia	1	8.3
United Kingdom	1	8.3
Total	**12**	**100**

Table 4 Year of publication on the included studies ($N=12$)

Year of publication	No. Studies	%
2018–2024	10	83.3
2012–2017	0	0
2006–2011	1	8.3
2000–2005	1	8.3
Total	**12**	**100**

2000–2024 ($N=12$). The complete study selection process is illustrated in the PRISMA flowchart (Fig. 1).

Synthesis of results

The comprehensive analysis of selected studies, including studies by and the study protocol established by, underscores the pivotal role that technology plays in improving self-care practices for individuals managing diabetic foot ulcer conditions [16–26].

These studies delve into various innovative technological interventions aimed at enhancing patient engagement and adherence to self-care routines. Notable interventions include mobile applications, which have gained traction as effective self-management tools. For instance, Marques et al. [20] evaluated a mobile app called PED-CARE designed to reinforce self-care routines through personalized reminders and visual guides. After 12 weeks, participants showed a significant increase in foot inspection frequency and retained more knowledge about ulcer prevention, demonstrating the application's usability in primary care settings. However, the small sample size ($n=30$) and absence of long-term follow-up limits the generalizability of the findings.

Similarly, Kılıç et al. [23] assessed a remote patient education application that delivers structured educational content and follow-up prompts. The study reported a reduction in risky behaviors and an improvement in self-reported understanding of DFU risk factors. conducted a randomized controlled trial assessing a behavioral change-oriented mHealth programme. The results indicated significant improvements in patient behavior modification, particularly in foot inspection frequency, footwear selection, and ulcer risk awareness. Firdaus et al. [24], along with educational resources such as instructional videos and informative booklets [16–19]. Additionally, tailored exercise software has been developed (20, 22;23–25). Ferreira et al. [19] introduced

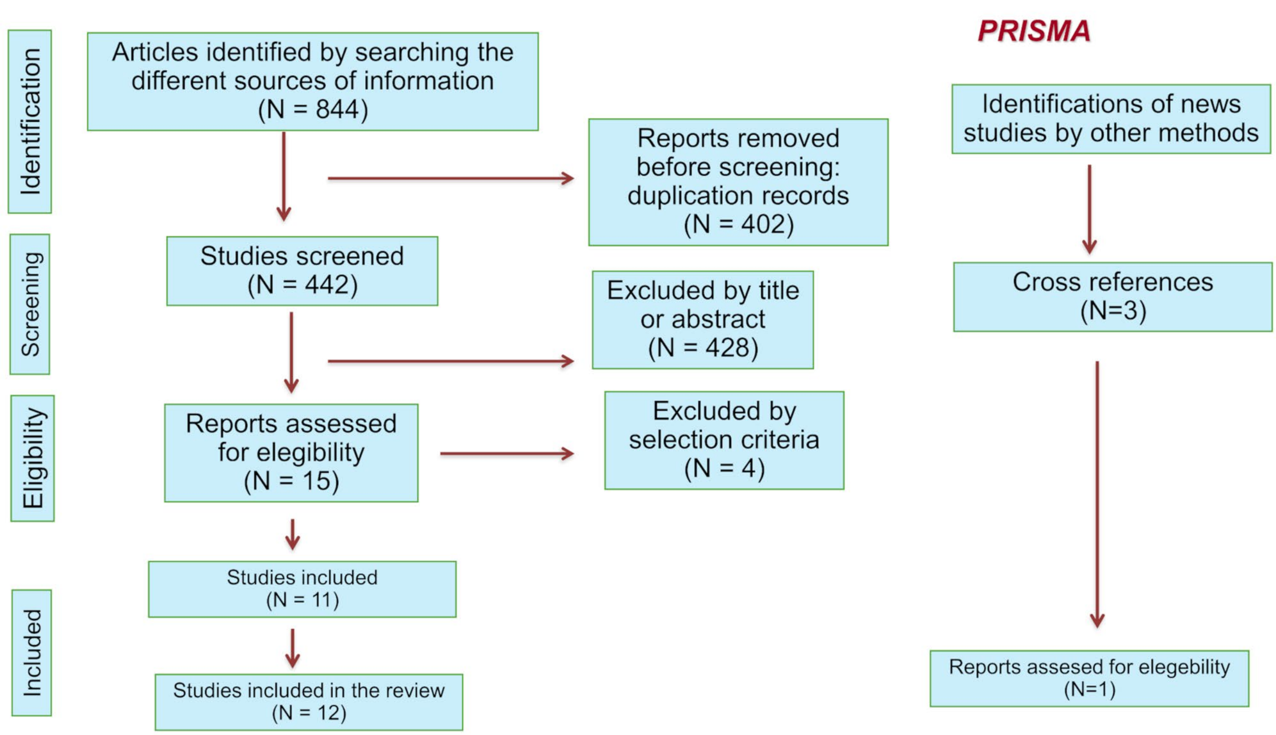

Fig. 1 Diagram PRISMA flowchart

custom-designed exercise software targeting foot and ankle mobility in patients with diabetes. The software promoted adherence to therapeutic physical activity and was perceived as user-friendly and adaptable to patient routines, thereby highlighting the value of personalized rehabilitation tools.

Other studies have explored wearable sensors that monitor pressure or temperature to detect early signs of ulcer development, showing promise for preventing complications. The inclusion of earlier landmark studies such as Lavery and Armstrong et al. ([17, 18]) enhances the scope of our review by providing foundational evidence for current technological applications. Lavery et al. [18], demonstrated that daily skin temperature monitoring could reduce ulcer recurrence by 70%, thereby setting a precedent for later sensor-based interventions. Armstrong's work contributed to the development of ulcer classification systems that are now integrated into decision-support tools within mHealth apps.

A consistent objective shared among these interventions is to enhance patient understanding and compliance with their self-care regimens, ultimately aiming to prevent serious complications, such as foot ulcers and potential amputations [16]. The studies exhibit a range of designs, methods of delivery, and specific outcome measures. For instance, some research focuses on delivering educational materials and reminders to patients [21], whereas others utilize interactive tools that offer personalized feedback to users. (19; 23)

Table 5 Analysis of self-care practices and their representation in diabetic foot care guidelines

Self-Care Variable (IWGDF & ADA Guidelines)	Percentage of Guideline Representation in the Study Selection
Daily foot inspections and shoe checks	85%
Proper foot hygiene (washing and drying)	75%
Use of emollients for skin hydration	70%
Straight nail trimming	65%
Avoid walking barefoot or with thin soles	80%
Use of appropriate footwear	78%
Structured patient and caregiver education	82%
Early detection and self-monitoring	68%
Recording foot health changes	64%
Regular risk assessment	72%
Avoid harsh chemicals for callus removal	60%
Monitoring foot temperature	55%
Patient engagement in self-care	74%
Use of mobile health programs	67%
Telemedicine and remote consultations	69%
Personalized feedback and support	71%
Adherence enhancement through reminders and notifications	76%

International Working Group on the Diabetic Foot (IWGDF), American Diabetes Association (ADA)

The data reveal the prominence of "adherence," "education," and "monitoring" within the guidelines, reinforcing their importance in effective diabetic foot ulcer care

This is particularly noteworthy, as it evaluates different educational strategies. It juxtaposes the efficacy of an instructional video with a guided reading leaflet in comparison to standard care practices. This demonstrates the increasing interest among researchers in ascertaining the relative effectiveness of various technological approaches in patient education and self-management. Ferreira et al. [25] published a study protocol for a pragmatic randomized trial aimed at evaluating an educational intervention for diabetic foot care. Although outcome data are not yet available, the protocol emphasizes integration with primary care and long-term behavioral tracking.

Overall, the reviewed studies, along with Ferreira et al.'s protocol, indicate a positive trend toward the integration of technology in empowering patients to take charge of their diabetic foot ulcer self-care. Nonetheless, further research is needed to evaluate the long-term effectiveness and cost-effectiveness of these interventions.

To illustrate the representation of self-care practices in relation to the established Diabetic Foot Ulcer Care Guidelines, Table 5 provides a detailed analysis. This reveals the percentage of studies that addressed various critical aspects of diabetic foot ulcer self-care, as recommended by the International Working Group on the Diabetic Foot Ulcer and the American Diabetes Association [27]. Notably, daily foot inspections, maintenance of proper hygiene, avoidance of barefoot walking, and selection of appropriate footwear were emphasized in >75% of the studies. Moreover, structured education for both patients and caregivers, coupled with adherence enhancement strategies utilizing reminders, was similarly highly represented (over 75%).

Other essential components, such as the use of emollients, nail trimming, early detection of foot issues, and engaging patients in their care, were discussed in a substantial majority of studies (ranging from 60 to 75%). However, certain practices, such as monitoring the foot temperature and avoiding harsh chemicals, were addressed less frequently, falling below 60%. The incorporation of mobile health initiatives, telemedicine, and the provision of personalized feedback were within a moderate range, specifically between 67% and 71%.

Collectively, these studies demonstrated the effectiveness of a wide spectrum of technologies in promoting self-care and reducing the risk of complications among patients with diabetes. The most promising interventions were those that combined educational components with real-time feedback and behavioral reinforcement, particularly mobile apps and telemonitoring platforms. However, heterogeneity in study designs, outcome measures, and sample sizes remains a limitation for meta-analysis.

Risk of bias between studies: The assessment of bias across studies using the Cochrane Risk of Bias Tool [28] showed that most articles demonstrated a low risk of bias, which increased the credibility of their findings. However, some studies may have been affected by performance bias, potentially undermining the validity of their results. This evaluation can inform future research efforts, help minimize bias, and enhance the quality of evidence in diabetic foot ulcer care studies.

Discussion

This scoping review methodically investigated the utilization of novel technologies in the domain of diabetic foot ulcer self-care, acknowledging a spectrum of interventions that have the potential to enhance patient outcomes. Previous studies have indicated a favorable trend in the adoption of technology for self-management and prevention of complications, thereby underscoring the significant role that mobile applications and analogous tools play in empowering patients to assume responsibility for their diabetic foot ulcer care. Lopes et al. [26] explored patient preferences and usability expectations for future mobile device applications. Through qualitative and quantitative assessments, this study revealed the importance of user-centered design, simplicity, and customization in technological tools for DFU management [16–26].

Key technologies include mobile applications, educational resources (digital and print), telehealth platforms, and wearable sensors. Telehealth platforms were also evaluated, emphasizing their role in facilitating timely interventions, especially in underserved populations or areas with limited access to specialized care. These platforms enable real-time data sharing and remote consultations, leading to better disease management and a reduced incidence of severe ulcers. These interventions focused on education, self-monitoring, adherence to treatment plans, and early issue detection. Studies have shown positive results such as improved patient knowledge, increased adherence to self-care practices, and reduced foot ulcer recurrence. Lavery et al. [18] reported on the impact of home temperature monitoring devices on DFU prevention. This study demonstrated that early detection of temperature deviations resulted in a reduction of up to 70% in ulcer recurrence rates, supporting the use of sensor-based self-monitoring technologies. Haycocks et al. [22] reported a mobile health application for individuals with recently healed foot ulcers. This intervention supported continued self-monitoring and reduced the risk of ulcer recurrence through real-time feedback and virtual support. The preliminary results demonstrated improved engagement and satisfaction among users. Additionally, educational tools, such as those validated by Galdino et al. [16], include a printed educational booklet focused on diabetic foot care. The intervention significantly enhanced patients' knowledge regarding hygiene, inspection, and ulcer prevention practices, demonstrating the efficacy of structured printed materials as a low-cost educational strategy. Menezes et al. [21] designed and validated an educational folder aimed at promoting preventive foot care behaviors. The visual and textual components were tailored to low-literacy users and showed improvements in patient awareness and proactive prevention practices.

A computer-aided learning system for diabetes education, aimed at both patients and primary care professionals, highlights the growing trend in diabetes management [29]. This system responds to the increase in diabetes cases and the expanding role of primary care in managing the condition, focusing on providing standardized training and ongoing education, particularly for non-specialist nurses. It prioritizes patient education for self-care and uses computer-aided learning as a cost-effective resource. The self-paced format helps to bridge the training gap in primary care. Formative evaluations were conducted to ensure that the material was relevant for both experts and users, with plans for ongoing development and assessment in place.

Impact of Technologies on Self-Management and Disease Prevention.

Each of these technological approaches demonstrates clear benefits in promoting self-management:

- Mobile applications facilitate personalized education, reminders, and self-monitoring, leading to increased adherence and early detection of complications [30–32].
- Wearables and sensors enable real-time monitoring of parameters, such as pressure and temperature, which helps predict and prevent ulcer progression.
- Telehealth platforms: expand access to healthcare professionals, allowing timely intervention and ongoing support, especially for patients with mobility limitations. Table 6.

Challenges persist in the widespread adoption and effective implementation of new technologies within the healthcare sector. Key considerations include cost, accessibility, user experience, and the integration of these technologies with existing healthcare systems. Moreover, there is a need for further investigation into the long-term effectiveness and cost-effectiveness of many interventions. The variability in study designs and outcome measures across the reviewed literature limits direct comparisons and hampers the ability to draw definitive conclusions. It is essential for future research to focus on conducting rigorous evaluations with standardized

Table 6 Comparison of technological approaches

Technology	Advantages	Disadvantages	Best Application Areas
Mobile apps	Personalization; easy communication	Limited by digital literacy and access	Education; adherence reinforcement
Wearables and sensors	Continuous monitoring; early warning	Costly; maintenance needed	Prevention of recurrence; pressure management
Telemedicine	Remote access; easy for follow-up	Requires infrastructure	Early detection; specialist access

outcome measures to accurately assess the true impact of these technologies on patient outcomes [33].

Additionally, exploring the potential of integrating various technological solutions into comprehensive care pathways may further enhance their overall effectiveness. This review highlights the promising role of emerging technologies in the management of DFUs; however, further research and development are essential to fully realize their benefits and ensure equitable access for all patients.

Overall, these studies emphasize the significant potential of digital health technologies such as mobile apps, wearables, and telemedicine in improving patient engagement, adherence, and early detection of complications. Nonetheless, limitations including small sample sizes, variability in intervention designs, and short follow-up periods underscore the need for more rigorous long-term studies.

The results indicated that mobile technologies and telemedicine platforms have the potential to enhance self-management among patients with diabetic foot ulcers (DFU). These tools facilitate real-time monitoring, provide personalized reminders, and improve communication with healthcare professionals, thereby substantially reducing the risk of severe complications.

The guidelines set forth by the International Working Group on Diabetic Foot Ulcer (IWGDF) [27] highlight the vital role of patient education and self-care in the prevention and management of diabetic foot ulcer complications. This aligns seamlessly with the focus of the scoping review on innovations in self-care technology. The IWGDF guidelines offer practical recommendations to effectively complement technology-based interventions. For instance, they emphasize the importance of regular foot examinations, appropriate footwear, and proper skin care.

These aspects can be enhanced and monitored through mobile applications, telehealth platforms, and wearable sensors, as indicated in this review. By integrating evidence-based recommendations of the IWGDF with innovative technological approaches, it is possible to establish a more comprehensive and effective framework for diabetic foot ulcer self-care. Such synergy could lead to improved patient outcomes and reduced incidence of diabetic foot ulcers [34].

Contribution to the field

Collectively, these articles offer valuable insights into the management and prevention of diabetic foot ulcer complications. They emphasized the critical importance of patient education, self-care practices, and the integration of technology as essential components for enhancing patient outcomes. These findings support the incorporation of educational interventions and mobile health applications as effective strategies for promoting self-management among individuals with diabetes.

Limitations and future directions

Although this study offers valuable insights into the use of digital technologies for diabetic foot ulcer care, it also highlights several areas for improvement. The considerable variability in intervention types and outcome measures across studies underscores the necessity for standardization of future research designs. By aligning these elements, we can strengthen the comparability of findings and support more effective meta-analyses, ultimately advancing evidence-based practice. Furthermore, long-term longitudinal studies are essential to evaluate the sustained effectiveness of interventions and their overall impact on patient quality of life.

The integration of digital tools presents substantial opportunities to enhance patient outcomes; however, real-world implementation faces notable barriers, such as digital illiteracy, limited interoperability with existing healthcare systems, and economic disparities. Technologies requiring frequent data entry or Internet access may be impractical for older adults or underserved populations. Based on the current evidence, mobile applications and video-based educational resources offer an optimal balance between accessibility and clinical utility. Future research should explore hybrid interventions that combine wearable devices with telemedicine, complemented by rigorous assessment of cost-effectiveness and sustainability.

Recommended technologies and future research directions

Platforms that seamlessly integrate remote monitoring with personalized educational components appear to be the most promising for delivering comprehensive care. To maximize their potential, it is advisable to conduct expanded longitudinal studies to evaluate their long-term benefits, cost-effectiveness, and scalability across diverse healthcare settings.

Conclusions

This scoping review highlights the exciting potential of emerging technologies for revolutionizing diabetic foot ulcer self-care. Diabetic foot ulcers and their complications are the leading causes of amputation and can have a significant impact on global health and economics. Thankfully, advancements in digital health are stepping up to address these challenges in remarkable ways. The studies we examined illustrate the power of mobile applications, wearable sensors, and telehealth platforms in enhancing patient education, boosting adherence to self-care practices, and enabling the early detection of complications. These innovations not only deepen patient understanding, but also encourage positive behavioral changes, ultimately reducing the risk of foot ulcer recurrence.

Mobile health applications stand out because they offer tailored reminders, seamless communication with healthcare providers, and real-time monitoring of vital health indicators. However, we must acknowledge that there are hurdles to overcome, including issues of accessibility, cost, and the need for better integration with current healthcare systems. Additionally, the variety in study designs and outcome measures highlights the importance of standardization in future research. Longitudinal studies focusing on cost-effectiveness and long-term benefits are essential.

By aligning these digital tools with established guidelines, such as those from the IWGDF, we can create a holistic approach to managing diabetic foot ulcer issues. This could significantly lessen the burden of this condition, enhance patients' quality of life, and serve as a scalable model for addressing other chronic diseases. The current body of research offers a promising foundation, and by addressing biases and improving methodological quality, we can further advance our understanding and management of diabetic foot ulcer complications. The continued exploration of innovative solutions in diverse populations is vital for this process.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions
[NGM, MFGA, EAM, JR]: Contributed to the conception and design of the study, data analysis, and drafted the introduction and methods sections.[NGM, PJBC, ATS, PLR, PVA, MAEC]: Conducted the literature search, extracted data, and wrote the results section.[NGM, EAM, MAPD]: Provided critical revisions to the manuscript and oversaw the overall writing process.All authors: Reviewed and approved the final version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This article does not contain any studies involving human participants or animals performed by any of the authors.

Competing interests
The authors declare no competing interests.

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