



From ulcer to remission: podiatric and technological strategies to prevent ulceration and amputation in the diabetic foot

De la úlcera a la remisión: estrategias podológicas y tecnológicas para prevenir la ulceración y la amputación en el pie diabético

Maikro Osvaldo Chávez Moya¹ 

Leodanis Hernández Cabrera¹ 

Lauren Martínez Ramírez¹ 

Mariam Alejandra González González¹ 

Andy Alonso Pazos¹ 

Laura Beatriz Fernández Feitó¹ 

Gabriela González Pernas¹ 

¹ Universidad de Ciencias Médicas de Villa Clara, Facultad de Medicina. Santa Clara, Cuba.

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Corresponding Author: Maikro Osvaldo Chávez Moya 

ABSTRACT

Introduction: diabetic foot ulcers precede most diabetes-related amputations and recur frequently, so prevention is as important as treatment. Objective: to synthesise the evidence on preventing ulceration and amputation in the diabetic foot: risk stratification, footwear and offloading, temperature monitoring, podiatric and integrated care, and the situation in Latin America. Methods: narrative review based on a non-systematic search of guidelines, systematic reviews, randomised trials, cohort studies and regional publications, with a qualitative synthesis in five areas. Development: foot ulcers affect roughly 18.6 million people yearly, recurring in 42% at one year and 65% at five. In a meta-analysis of five randomised trials, home temperature monitoring was associated with lower ulceration risk (RR 0.51), although the largest trial showed no significant reduction in its primary outcome. Pressure-optimised footwear and structured education also appear useful, with wide confidence intervals. Non-removable knee-high offloading is first choice for neuropathic plantar ulcers, and about half of affected people have peripheral artery disease. Podiatric care before ulceration was associated with lower risk of amputation or death in dialysis patients (HR 0.89). Latin American data are scarce: in Argentina, only 3 in 10 people with diabetes had a foot examination in the previous year. Conclusions: preventing ulcer recurrence, understood as maximising ulcer-free days, should organise diabetic foot care. This requires systematic screening, pressure-relieving footwear, timely offloading and referral, integrated care including podiatry, and regional studies validating tools and remote monitoring.

Keywords: Amputation, Surgical; Diabetic Foot; Foot Ulcer; Podiatry; Secondary Prevention

RESUMEN

Introducción: las úlceras del pie diabético preceden a la mayoría de las amputaciones por diabetes y recurren con frecuencia, por lo que prevenir importa tanto como tratar. Objetivo: sintetizar la evidencia sobre prevención de la ulceración y la amputación: estratificación del riesgo, calzado y descarga, monitorización de temperatura, atención podológica e integrada y América Latina. Métodos: revisión narrativa con búsqueda no sistemática de guías, revisiones sistemáticas, ensayos, cohortes y publicaciones regionales, con síntesis cualitativa. Desarrollo: las úlceras afectan a unos 18,6 millones de personas al año y recurren el 42 % al año y el 65 % a los cinco. En un metaanálisis de cinco ensayos, la monitorización domiciliar de la temperatura se asoció con menos ulceración (RR 0,51), aunque el mayor ensayo no redujo significativamente su desenlace primario. El calzado optimizado para la presión y la educación estructurada parecen útiles, con intervalos amplios. La descarga no extraíble hasta la rodilla es la primera opción en úlceras plantares neuropáticas; cerca de la mitad de los afectados tiene enfermedad arterial periférica. La atención podológica previa se asoció con menor riesgo de amputación o muerte en diálisis (HR 0,89). Los datos latinoamericanos son escasos: en Argentina, 3 de cada 10 personas con diabetes se examinó los pies el último año. Conclusiones: prevenir la recurrencia (maximizar los días libres de úlcera) debe organizar la atención: cribado sistemático, calzado que alivie la presión, descarga y derivaciones oportunas, atención integrada con podología y estudios regionales que validen herramientas y monitorización remota.

Palabras clave: Amputación Quirúrgica; Pie Diabético; Podiatría; Prevención Secundaria; Úlcera del Pie

INTRODUCTION

Diabetes mellitus affects about 589 million adults aged 20 to 79 years worldwide, and the figure is projected to reach 853 million by 2050.⁽¹⁾ Among its complications, foot ulcers are among the most devastating: they are estimated to affect about 18.6 million people each year and are associated with amputation and death.⁽²⁾ After ulceration, 5-year mortality is around 30% and exceeds 70% in those who suffer a major amputation.⁽²⁾

The problem does not end with healing. It is estimated that 42% of healed ulcers recur within a year and 65% at 5 years.⁽²⁾ Therefore, international guidelines have shifted the focus from wound closure to increasing ulcer-free days,⁽³⁾ an approach often summarized by the term diabetic foot remission.

Podiatry occupies a central position in this continuum, from screening and education to offloading, therapeutic footwear, treatment of pre-ulcerative lesions, and timely referral. ^(3,4) At the same time, remote monitoring technology offers new tools for home follow-up. ^(5,6) However, the evidence on which interventions work, and for whom, is heterogeneous, and data from Latin America are comparatively scarce.

The aim of this narrative review is to synthesize the evidence on the prevention of ulceration and amputation in the diabetic foot, with emphasis on risk stratification, footwear and offloading, temperature monitoring, the role of podiatric and integrated care, and the situation in Latin America, in order to identify implications for clinical practice and the organization of services.

METHODS

A narrative literature review was conducted, a design appropriate for the interpretive integration of heterogeneous evidence: clinical practice guidelines, systematic reviews and meta-analyses, randomized trials, cohort studies, and regional publications. The search was non-systematic and relied on PubMed/PMC, the portals of the International Working Group on the Diabetic Foot (IWGDF) and the International Diabetes Federation, and regional open-access journals.

Priority was given to studies with empirical data or formal recommendations on prevention of ulceration and its recurrence, stratification and classification, offloading, management of infection and peripheral arterial disease, and organization of care. Advanced healing therapies, reconstructive surgery, and Charcot neuroarthropathy were excluded, as they exceed the scope of this review. Selection was purposive and the qualitative synthesis was organized into 5 axes: burden and screening gaps; stratification and classification; prevention of ulceration and its recurrence; treatment of the established ulcer; and podiatric and integrated care. The risk of bias of the sources was not formally assessed.

Development

Burden, Inequalities, and Screening Gaps

Neurological, vascular, and biomechanical factors jointly contribute to ulceration,⁽²⁾ and the vast majority of people with an ulcer have neuropathy.⁽⁴⁾ Only between 30 and 40 % of ulcers heal at 12 weeks.⁽²⁾ The burden is not distributed homogeneously: in the United States, Black, Hispanic, or Native American people and those of lower socioeconomic status have more ulcers and more subsequent amputations than White people.^(2,7)

In Latin America, the available information suggests gaps in early detection. According to data from the 4th National Survey of Risk Factors of Argentina, presented at a symposium on diabetic foot guidelines, only 3 out of 10 people with diabetes had had a foot examination in the last year.⁽⁸⁾ In Peru, it has been reported that diabetic foot motivates one in five hospital admissions of people with diabetes.⁽⁹⁾

Risk stratification and ulcer classification

The IWGDF prevention guideline establishes annual screening for loss of protective sensation and peripheral arterial disease in people at very low risk of ulceration (category 0), and more frequent screening, including screening for additional risk factors, in those at higher risk (categories 1 to 3).⁽³⁾

Once the ulcer is established, the classification serves different purposes. The systematic

review that supported the IWGDF classification guideline identified 28 systems described in 149 articles. The 2023 recommendations propose using SINBAD for communication between professionals and for the audit of population outcomes, the IDSA/IWGDF classification for infection, and the Wifl system when peripheral arterial disease coexists. (10)

In Latin America, systems of regional origin are also used, such as the San Elián classification. A systematic review with meta-analysis of 15 studies from nine countries identified five scales (IDSA, San Elián, Wifl, Meggitt-Wagner and University of Texas); for amputation of any level, the Wagner scale with a threshold at grade 3 showed the highest sensitivity (0.91) and San Elián the highest positive likelihood ratio (4.1). (11) An external validation study of a retrospective cohort of a diabetic foot unit in Lima (2015-2019) found a cumulative incidence of amputation greater than 11% at six months and an area under the ROC curve of 0.90 for San Elián, compared to 0.81 for the Texas and Meggitt-Wagner classifications, and 0.74 for SINBAD. (9) As a single center, these results do not replace international recommendations, but support the validation of the tools in local contexts.

Prevention of ulceration and its recurrence

The IWGDF recommendations for people at risk include education on foot self-care and on not walking without adequate protection, treating any preulcerative lesion, prescribing well-fitted and accommodative therapeutic footwear for those at moderate or high risk, and considering training them to monitor foot skin temperature. To prevent recurrence of a plantar ulcer, therapeutic footwear with a demonstrated effect in relieving plantar pressure during walking is recommended, and it is suggested that nerve decompression not be used. The guideline also recommends offering integrated foot care to people at moderate or high risk. (3)

A systematic review with meta-analysis by the IWGDF found moderate-certainty evidence that temperature monitoring (5 trials; RR 0.51; 95% CI: 0.31-0.84) and pressure-optimized footwear or insoles (2 trials; RR 0.62; 95% CI: 0.26-1.47) probably reduce plantar ulcer recurrence in high-risk individuals. Structured education (RR 0.66; 95% CI: 0.37-1.19), therapeutic footwear (RR 0.53; 95% CI: 0.24-1.17), flexor tenotomy, and integrated care (3 trials; RR 0.78; 95% CI: 0.58-1.06) showed low certainty. (12) Several of these intervals include the absence of effect, so the point estimates should be interpreted with caution.

Temperature monitoring requires careful interpretation. A meta-analysis of five trials with 772 participants at IWGDF risk 2 or 3, who measured temperature at home at six or more sites on each foot and reduced activity in the presence of differences greater than 2.2 °C between homologous sites, found a lower risk of ulcer (RR 0.51; 95% CI: 0.31-0.84), with low certainty according to the authors. (13) The DIATEMP trial, the largest to date, assigned 304 people to usual care (which already included podiatric treatment, education, and therapeutic footwear) or to that care plus daily temperature measurement. The primary outcome, recurrence on the plantar or interdigital surface, or at the medial, lateral, or anterior forefoot at 18 months, was not significantly reduced (relative reduction of 22%), although recurrence at any site of the foot was reduced (RR 0.76; 95% CI: 0.579-0.997). The authors conclude that the benefit depends on participants reducing their ambulatory activity when they detect hot spots. (14) In the economic analysis, recurrence was 36% with monitoring versus 47% with usual care, but the probability that the intervention was cost-effective at the considered threshold was 45%. (15)

Digital technologies expand these possibilities. The latest guidelines promote a shift from isolated hospital treatment toward integrated community prevention, in which wearable devices and digital tools make it possible to monitor risk factors, empower patients in their self-care, and bring multidisciplinary prevention closer to those living far from services. (5) A systematic review of sensor technologies and wearable devices describes the measurement of plantar pressure and shear, temperature, humidity, perfusion, and pH, with alerts to patients and professionals. (6) This is a synthesis of technologies, and its clinical effectiveness must be demonstrated in trials.

Treatment of the established ulcer: offloading, infection, and ischemia

Surgical debridement, reduction of weight-bearing pressure, treatment of ischemia and infection, and early referral to multidisciplinary care constitute the first line of treatment. (2) The IWGDF offloading guideline considers offloading to be the most important of the interventions required to heal an ulcer. For a neuropathic plantar ulcer of the forefoot or midfoot, it recommends as a first option a non-removable knee-high offloading device; as a second option, a removable knee-high or ankle-high device; and, if devices are not available, appropriate footwear with felt. (16)

Regarding infection, the IWGDF/IDSA guideline recommends clinically diagnosing infection based on local or systemic signs of inflammation, classifying its severity using the IDSA/IWGDF

system, using magnetic resonance imaging when doubt persists regarding osteomyelitis, and not treating uninfected ulcers with antibiotics for preventive or healing purposes.(17) Approximately 50 % of people with diabetes and an ulcer have peripheral arterial disease, which significantly increases the risk of adverse limb and cardiovascular events.(18) Therefore, vascular assessment should be part of the evaluation of every ulcer.

The role of podiatric and integrated care

One retrospective cohort study of 14 935 Medicare beneficiaries with type 2 diabetes on dialysis and a newly diagnosed ulcer evaluated the podiatric care received during the 3 months before diagnosis, which was received by only 18,4 % of patients. Those who received it had an 11 % lower risk of death or amputation (HR 0,89; 95 % CI: 0,84-0,93) and a 9 % lower risk of major amputation. The authors note that the frequency of podiatric care was not available and that studies with greater statistical power are required.(19) Given its observational design, these results do not demonstrate causality.

Across the trials, integrated foot care showed a low-certainty effect (RR 0.78), with a confidence interval that includes unity. (12) Nevertheless, the IWGDF prevention guideline recommends it for people at moderate or high risk,(3) and early referral to multidisciplinary care is part of first-line therapies.(2) The evidence identified in this review does not allow the specific effect of the podiatry professional to be isolated in randomized trials.

Table 1. Prevention and treatment of the diabetic foot: main findings and evidence gaps

Domain	Main findings	Gaps and considerations
Screening and stratification	Annual screening for very low risk, with more frequent screening for categories 1 to 3. (3) In Argentina, only 3 of every 10 people with diabetes receive an annual foot examination. (8)	Heterogeneous screening coverage and limited regional data. (8)
Classification	SINBAD for communication and auditing; IDSA/IWGDF for infection; and Wifl for peripheral arterial disease. (10) San Elián showed an AUROC of 0.90 in a center in Lima. (9)	Regional evidence from a single center and a regional meta-analysis with heterogeneity of scales. (9,11)
Education and footwear	Footwear or pressure-optimized insoles (RR 0.62; moderate certainty) and structured education (RR 0.66; low certainty). (12)	Wide confidence intervals that include the absence of effect. (12)
Temperature monitoring	RR 0.51 in the meta-analysis of 5 trials. (13) Recurrence at any site: 36% vs. 47%. (15)	No significant effect on the primary outcome of DIATEMP; the effect depends on reducing activity at hot spots; cost-effectiveness is uncertain. (14,15)
Ulcer discharge	Non-removable device up to the knee as a first-line option for neuropathic plantar ulcer. (16)	Removable alternatives or felt footwear if there is a contraindication or if devices are not available. (16)
Infection and ischemia	Clinical diagnosis of infection; do not treat uninfected ulcers with antibiotics. (17) Approximately 50% of people with ulcers have peripheral arterial disease. (18)	Requires multidisciplinary coordination with vascular assessment. (2,18)
Podiatry and integrated care	Podiatric care prior to ulcer is associated with a lower risk of death or amputation in dialysis (HR 0.89). (19) Integrated care: RR 0.78. (12)	Observational study with unknown frequency of care; low certainty regarding integrated care. (12,19)
Digital technology	Sensors and wearable devices for remote monitoring and community prevention. (5,6)	Clinical effectiveness remains to be demonstrated in trials. (6)

Source: own elaboration based on the cited references. RR: relative risk; HR: hazard ratio; AUROC: area under the ROC curve.

DISCUSSION

The reviewed evidence converges on the conclusion that recurrence prevention should be the organizing principle of diabetic foot care. Because, after a healed ulcer, recurrence reaches 42 % per year,(2)the operational objective of increasing ulcer-free days(3)requires maintaining follow-up after discharge, not only closing the wound. Risk stratification, pressure-relieving footwear, and timely offloading of the established ulcer are the pillars supported by international guidelines.(3,16)

The quality of the evidence is uneven. Temperature monitoring illustrates the problem well: the meta-analysis of trials suggests a halving of risk, (12,13) but the largest trial did not confirm this finding in its primary outcome, and its benefit appears to depend on adherence to activity reduction.(14)The economic evaluation was also inconclusive.(15)Accordingly, the IWGDF makes the recommendation with caution (consider monitoring in people at moderate or high risk),(3) and states that the incorporation of this technology into services requires educational support and not only the provision of devices.

The evidence on the role of podiatry comes mainly from observational studies, with the inherent limitations of confounding by indication and lack of information on visit frequency.(19) Nonetheless, the association with fewer amputations and deaths, the recommendation for integrated care, and the indication for early referral suggest that podiatry should be integrated into multidisciplinary teams that include, as appropriate, internal medicine, vascular surgery, infectious diseases, and orthotics.(2,3,19)Trials or quasi-experimental studies that isolate its specific contribution are needed.

In Latin America, the data indicate that the main gap is at the first step: screening. If only 3 out of every 10 people with diabetes receive an annual foot examination, as reported in Argentina,(8)most cases will present to the health system with an already established ulcer. Regional classification studies are useful, but they come from a single center or from meta-analyses with heterogeneous scales, (9,11) and they do not replace the need for studies that measure the impact of prevention programs on the incidence of ulcers and amputations in the region. Remote monitoring technologies could help reduce barriers to access, especially in remote areas,(5)but their cost-effectiveness and equity of access have not yet been established.(6,15)

Research priorities include pragmatic trials for recurrence prevention in resource-limited settings, local validation of classification and screening tools, assessment of the effectiveness and cost of remote monitoring and wearable devices, and studies that isolate the effect of podiatric care and of integrated care models.

This review has limitations: the search was not systematic, and the selection was purposive, so selection bias may exist; some regional sources are symposium abstracts or single-center studies; the risk of bias in the studies was not assessed; and advanced wound-healing therapies, reconstructive surgery, and Charcot neuroarthropathy were excluded. The results should be read as a map of the evidence rather than as a quantitative estimate of the effect of each intervention.

CONCLUSIONS

Diabetic foot care should be organized around preventing recurrence and increasing ulcer-free days. To this end, the evidence supports systematic screening and stratification, therapeutic footwear that relieves pressure, offloading with non-removable devices for neuropathic plantar ulcers, assessment of infection and peripheral arterial disease, and early referral to integrated care, in which podiatry plays a central role. Home temperature monitoring and digital technologies are promising, but their results are heterogeneous and their implementation depends on adherence and access. In Latin America, the priority is to expand screening and generate regional evidence that validates tools and evaluates prevention programs in contexts where the burden is greatest.

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20. Conceptualización: Maikro Osvaldo Chávez Moya, Leodanis Hernández Cabrera, Gabriela González Pernas.
21. Metodología: Laura Beatriz Fernández Feitó, Lauren Martínez Ramírez.
22. Investigación: Mariam Alejandra González González, Andy Alonso Pazos, Leodanis Hernández Cabrera.
23. Análisis formal: Gabriela González Pernas, Maikro Osvaldo Chávez Moya.
24. Redacción - borrador inicial: Lauren Martínez Ramírez, Andy Alonso Pazos.
25. Redacción - revisión y edición: Laura Beatriz Fernández Feitó, Mariam Alejandra González González, Leodanis Hernández Cabrera.
26. Supervisión: Maikro Osvaldo Chávez Moya.

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AUTHORSHIP CONTRIBUTIONS

Drafting – original draft: Maikro Osvaldo Chávez Moya, Leodanis Hernández Cabrera, Lauren Martínez Ramírez, Mariam Alejandra González González, Andy Alonso Pazos, Laura Beatriz Fernández Feitó, Gabriela González Pernas.

Writing–review and editing: Maikro Osvaldo Chávez Moya, Leodanis Hernández Cabrera, Lauren Martínez Ramírez, Mariam Alejandra González González, Andy Alonso Pazos, Laura Beatriz Fernández Feitó, Gabriela González Pernas.