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REVIEW

Telepodiatry and smart insoles for remote monitoring of the diabetic foot

Telepodología y plantillas inteligentes para la monitorización remota del pie diabético

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ABSTRACT

Diabetic foot ulcers are a frequent and recurrent complication of diabetes that precede most lower-extremity amputations, and access to specialized foot care remains uneven across regions. This narrative review synthesizes the evidence on two technologies for remote monitoring of the diabetic foot: telepodiatry and smart insoles. Randomized trials indicate that telemedicine for diabetic foot ulcer care shortens healing time and that telemedical plantar temperature monitoring is feasible in high-risk patients, building on older trials of home thermometry. Smart insoles detect offloading adherence and plantar pressure patterns, and continuous temperature-monitoring socks and insoles capture early inflammatory signals, although most devices remain at the prototype or pilot stage. Adherence to remote monitoring is generally high but declines over time and depends on usability, feedback and workflow integration. The field converges on multimodal sensing that combines pressure, temperature and imaging with remote supervision, but clinical endpoint trials, standardized validation and equity-oriented implementation are still scarce. These technologies can extend specialist podiatric care beyond the clinic, yet their clinical benefit for ulcer prevention and recurrence still requires confirmation in pragmatic trials.

Keywords: diabetic foot; telemedicine; wearable electronic devices; foot orthoses; remote monitoring; foot ulcer.

RESUMEN

Las úlceras del pie diabético son una complicación frecuente y recurrente que precede a la mayoría de las amputaciones de la extremidad inferior, y el acceso a la atención podológica especializada sigue siendo desigual. Esta revisión narrativa sintetiza la evidencia sobre la telepodología y las plantillas inteligentes para la monitorización remota del pie diabético. Los ensayos aleatorizados indican que la telemedicina acorta el tiempo de cicatrización y que la monitorización telemática de la temperatura plantar es factible en pacientes de alto riesgo, sobre ensayos previos de termometría domiciliaria. Las plantillas inteligentes detectan la adherencia a la descarga y los patrones de presión, y los calcetines y plantillas de temperatura continua captan señales inflamatorias tempranas, aunque la mayoría de los dispositivos siguen en fase de prototipo o piloto. La adherencia suele ser alta, pero disminuye con el tiempo y depende de la usabilidad, la retroalimentación y la integración en los flujos de trabajo. El campo converge hacia el sensado multimodal que combina presión, temperatura e imagen con supervisión remota, aunque escasean los ensayos de desenlaces clínicos, la validación estandarizada y la implementación orientada a la equidad. Estas tecnologías pueden extender la atención podológica más allá de la consulta, pero su beneficio en prevención y recurrencia de úlceras requiere confirmación en ensayos pragmáticos.

Palabras clave: pie diabético; telemedicina; dispositivos electrónicos vestibles; ortesis del pie; monitorización remota; úlcera del pie.

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INTRODUCTION

Diabetic foot ulcers are among the most frequent and costly complications of diabetes. A recent comprehensive review estimates that foot ulcers affect roughly 6% of people with diabetes worldwide and precede the large majority of nontraumatic lower-extremity amputations, with recurrence rates that remain high even after the wound has closed.(1,2) Ulceration is driven by the combination of peripheral neuropathy, foot deformity and repetitive plantar pressure, and its natural history is shaped by delayed detection, infection and uneven access to specialized care.(3)For health systems, the consequence is a cascade of outpatient visits, hospital admissions and procedures that concentrate where podiatric and vascular services are least available.(4)The progression from ulcer to amputation is not inevitable, yet once an ulcer develops the risk of infection, hospitalization and limb loss rises sharply, which places a premium on detection before skin breakdown.(1)

The COVID-19 pandemic accelerated the shift toward remote care and exposed the fragility of in-person diabetic foot services. Face-to-face consultations were reduced or interrupted in many countries, wound clinics were repurposed, and both patients and clinicians turned to telephone, video and image-based follow-up to maintain continuity.(5,6) That experience renewed interest in technologies that could monitor the diabetic foot away from the clinic, either by moving the consultation itself to a distance or by measuring the physical signals that anticipate ulceration.(7)Digital health reviews describe this as a durable shift rather than a temporary substitution, with remote follow-up now embedded in many diabetes services even where in-person care has resumed.(6)

Two complementary technologies concentrate this effort. Telepodiatry uses telecommunications and digital imaging to deliver podiatric assessment, wound review and education at a distance, and a meta-analysis of randomized trials indicates that this pathway improves wound outcomes in people with diabetic foot ulcers.(8)Smart insoles embed pressure, temperature or inertial sensors in footwear to quantify the mechanical and thermal state of the plantar surface during daily life, sometimes combined with machine learning and remote data transmission.(9,10) Modern systems typically integrate arrays of pressure sensors, temperature sensors or inertial units, transmit data wirelessly for offline analysis, and in some designs return feedback through vibration or a paired application.(9)Both approaches share a common logic: detect the pre-ulcerative signal or the deteriorating wound early, so that offloading and treatment can be intensified before tissue breakdown or amputation.(11)

Foot temperature has the longest clinical history as a monitoring signal. Randomized trials conducted two decades ago showed that structured home monitoring of foot skin temperature reduced ulceration in high-risk patients, first in a cohort of 85 people and later in a blinded 18-month trial of 225 participants.(12,13) Those findings established a preventive principle that connected, sensor-equipped footwear now attempts to deliver continuously and at scale.(14)

The two technologies can be read as five dimensions of a single remote monitoring system. Telehealth defines the delivery channel, plantar pressure and plantar temperature define the physiological signals, technical performance defines the quality of those signals, and implementation defines whether the system is used. Organizing the evidence along these dimensions makes the gaps in each visible and allows the clinical reader to judge which components are ready for practice and which remain experimental.

The literature on these technologies is dispersed across clinical trials, device engineering and implementation studies, and it has grown rapidly but unevenly. For this reason a narrative synthesis organized by dimension is timely: it can map what each technology measures, how well the measurements perform, and whether they change outcomes or behavior. The objective of this review was to synthesize the evidence on telepodiatry and smart insoles for remote monitoring of the diabetic foot. The specific objectives were to describe telehealth models for diabetic foot care, to synthesize the evidence on smart insoles for plantar pressure monitoring, to synthesize the evidence on smart insoles for plantar temperature monitoring, to examine technical performance and data processing, and to analyze implementation dimensions and the relations among these axes.

DEVELOPMENT

The synthesis drew on 42 studies distributed across five thematic axes: 8 on telehealth models, 10 on plantar pressure sensing, 8 on plantar temperature sensing, 8 on technical performance and 8 on implementation. These counts reflect the argument matrix and are descriptive rather than a claim of exhaustiveness. Each axis is presented with the same internal structure: the state of the evidence, the points of convergence, and the points of divergence and remaining gaps.

Telehealth models for diabetic foot care

The state of the evidence in this dimension rests on two randomized trials, several observational cohorts and a small number of qualitative and evaluation studies. A single-centre randomized trial compared telemedicine in home healthcare with routine follow-up for people with diabetic foot ulcers, measuring wound healing time, wound score and patient self-management in a design in which the remote pathway replaced part of the usual face-to-face visits.(15)A separate single-centre randomized trial evaluated telemedical treatment of diabetic foot ulcers in rural and remote areas, where specialist wound services are scarce.(16)Observational work points in the same direction: a retrospective cohort found that WeChat-based remote care guidance was associated with ulcer healing in routine practice,(17)and a report on embedding artificial intelligence in remote follow-up described the transition from store-and-forward telemedicine to automated early warning for wound deterioration.(18)This progression matters because store-and-forward requires a clinician to review every image, whereas automated triage could direct attention to the minority of cases that are actually worsening, a difference with direct implications for service capacity.(18)The feasibility of in-home imaging was documented through a full-colour imaging scale for high-risk feet, which proved usable for remote assessment of skin changes before a visible ulcer forms.(19)On the qualitative side, a realist evaluation of cross-sectoral telemedicine described the organizational conditions under which remote diabetic foot care succeeds or fails,(20)and clinicians providing telehealth to Aboriginal patients with diabetic foot complications identified infrastructure, workflow and cultural barriers.(21)A synthesis of podiatric and technological strategies complements these reports by framing the pathway from ulcer to remission as one in which remote monitoring supports, rather than replaces, structured foot care.(11)

The convergence across these studies is that remote consultation and image-based follow-up can substitute for part of the in-person pathway without obvious loss of wound surveillance, provided the service is organized around a defined workflow rather than added to existing routines.(19,20) Findings diverge mainly on the strength of the evidence: the trials were single-centre and modest in size, and the observational cohorts cannot exclude confounding by case selection, so the improvement in healing time reported in one setting has not yet been reproduced in large multicentre designs.(15,17) A further gap is the scarcity of head-to-head comparisons between video consultation, store-and-forward imaging and automated triage, and the near absence of cost and equity outcomes in the reports available to date. The balance of this evidence supports a staged model in which remote follow-up is reserved for stable wounds and high-risk feet, with in-person review reserved for suspected infection or ischemia, although no study yet tests that triage rule prospectively.(16,19) The organizational realism of the qualitative studies also suggests that the same platform can succeed in one service and fail in another, which makes the reporting of context essential for future evaluations.(20)

Smart insoles for plantar pressure monitoring

This axis gathers the largest body of work, although most of it sits at the interface between device development and early clinical evaluation. Two studies address offloading adherence directly. A randomized clinical trial of sensor-assisted wound therapy used sensors to detect removal of the offloading device in people with plantar diabetic foot ulcers, on the premise that device removal delays healing; the rationale is that offloading limits mobility and carries psychological and cardiovascular side effects, so detection of removal flags the moments when protection is lost.(22)The SmartBoot platform monitored patient activity and offloading use in real time through remote edge computing and reported that adherence, although critical for healing, remained inadequate without feedback.(23)The platform architecture matters clinically because real-time monitoring closes the loop between the act of removing the device and the clinical response, in contrast to pressure maps that are reviewed only at the next visit.(23)Plantar pressure measurement itself is supported by a cloud-based monitoring system designed for self-care, a low-cost piezoresistive insole with convolutional network classification of diabetic foot risk patterns, and a custom-topology Velostat insole aimed at pressure redistribution in diabetic foot care.(24-26)Multi-modal sensor fusion in smart footwear captured altered gait dynamics in diabetic peripheral neuropathy,(27) and a pressure-altering smart insole was piloted in healthy adults with implications for neuropathic feet.(28)Complementary studies linked in-shoe plantar temperature with normal and shear stress during gait, prototyped active offloading footwear based on magnetorheological modules that respond to the loaded state, and described a shear-sensitive smart textile intended for early detection and offloading rehabilitation.(29-31)

The available evidence converges on the conclusion that pressure-sensing insoles can mea-

sure the mechanical exposure that drives ulceration and can quantify whether an offloading prescription is actually being followed.(22,23) They diverge in maturity: the adherence findings come from a randomized trial and a monitoring platform, whereas most pressure-classification systems remain laboratory-validated prototypes without demonstration of reduced ulcer incidence.(25,26) The principal gap is the missing link between a detected pressure pattern or an adherence event and a prevented ulcer, which would require trials with ulceration or recurrence as the endpoint rather than sensor accuracy alone.(28)For the clinician, the immediate utility of these devices is therefore less diagnostic than supervisory: they answer whether the prescribed offloading is happening, a question that no office visit can resolve retrospectively.(22)A second unresolved point is whether the pressure signals that matter for ulceration are the peaks, the cumulative load or the duration of weight-bearing, and current prototypes emphasize different metrics, which complicates comparison across systems.(25,27)

Smart insoles and footwear for plantar temperature monitoring

The temperature axis has the strongest biological rationale, because plantar temperature anticipates ulceration through the inflammatory response that precedes tissue breakdown. The most direct contemporary evidence comes from a randomized trial of telemedical monitoring of plantar temperature in people with diabetes and peripheral neuropathy at risk of foot ulcers, which tested daily temperature surveillance with remote feedback against standard care.(2)The trial background notes that ulcer prevalence reaches 6.3% among people with diabetes and that early detection of asymmetrical plantar temperature elevation, followed by reduction of weight-bearing on the affected foot, is the preventive mechanism under test.(2)An open-label randomized trial in a low-medical-resource setting tested a nurse-led, thermography-guided preventive foot care protocol against standard care in people with a history of diabetic foot ulcer.(32)

Alongside the trials, device studies established that continuous temperature monitoring can be delivered in ordinary footwear. An observational study of temperature-monitoring socks documented their use at home by people with diabetes,(33)and a pilot study related skin temperature measured with smart socks to plantar pressure distribution.(34)More recent prototypes include a laser-induced graphene insole for measuring plantar temperature, an approach motivated by the observation that existing real-time plantar temperature systems remain limited in availability and relatively expensive, so materials that lower cost could widen access(35)and a prospective cohort that explored the value of continuous plantar temperature monitoring and found that daily single readings, the current guideline standard, can misclassify signal as noise.(36)Comparative physiology studies confirmed that plantar temperature in stance differs between people with and without diabetic neuropathy, supporting temperature as a surrogate of tissue perfusion.(29,37) One development line combined the thermal and mechanical domains in temperature- and pressure-regulating insoles intended to cool plantar tissue while redistributing pressure.(38)

This literature converges on the biological rationale and on the feasibility of continuous temperature monitoring at home.(33,35) They diverge on the clinical threshold and the monitoring frequency: the classic principle relied on a fixed asymmetry between contralateral sites, whereas continuous monitoring raises questions about which temperature deviation justifies an alert and about how many measurements are needed to avoid false alarms.(36)The main gaps are the absence of a large pragmatic trial reporting ulcer incidence as the primary outcome with a modern continuous device, and the limited evidence on temperature monitoring among people with peripheral arterial disease, in whom perfusion confounds the temperature signal.(32)The cumulative picture is that temperature monitoring has moved from a research tool to a connected clinical tool without yet settling the alerting logic that would make continuous data clinically actionable.(36)The physiology data also indicate that temperature responds to posture and weight-bearing and not only to inflammation, so interpretation must separate the loading artifact from the inflammatory signal before an alert is issued.(37)

Technical performance, data processing and validation

The technical axis documents what the devices actually measure and how reliably. Smart insoles that combine pressure and temperature have been implemented with piezoresistive sensors, screen-printed nanomaterials and fibre Bragg gratings, each with distinct linearity, drift and durability profiles.(39-41)The choice of sensing technology also conditions what else the insole can measure: fibre Bragg gratings are insensitive to electromagnetic interference and suited to combined pressure and temperature readouts, whereas piezoresistive films trade some robustness for low cost and ease of fabrication.(40,41) Sensor placement has been optimized for centre-of-pressure

estimation, showing that a reduced number of well-placed sensing points can preserve accuracy and lower cost.(42)A review of sensor insoles summarized the sensing technologies and their trade-offs,(9)and a systematic review of wearable technologies for diabetic foot ulcer monitoring and risk prediction concluded that continuous measurement of pressure and temperature is technically mature but that standardized validation is lacking.(10)Low-cost thermal cameras were shown to require radiometric drift correction, vignetting compensation and geometric calibration before they can support clinical thermography.(43)A threat-modelling analysis further identified cybersecurity vulnerabilities in smart insole systems used in diabetes care, covering devices that measure pressure, temperature and gait for ulcer and amputation prevention and singling out the data transmission pipeline as the weakest point.(44)

The convergence is that the sensing hardware is no longer the limiting factor: multiple technologies can resolve the pressure and temperature signals of interest at acceptable cost.(39,40) The divergence concerns measurement quality in real use. Laboratory accuracy exceeds in-shoe accuracy because of sensor drift, crosstalk between neighbouring cells, shear loading and foot-to-insole interface variability, which the reviews flag as the main source of disagreement across studies.(9,10) The gap is the absence of consensus validation protocols that would let clinicians compare one insole against another, together with the unresolved questions of calibration over months of wear and of data quality control for the remote cloud pipelines that these systems depend on.(42,44) In practical terms, the bottleneck has moved from the sensing layer to the interpretation layer, where the field still lacks a shared definition of what constitutes a valid in-shoe measurement.(10) Beyond the hardware, the processing chain that turns raw sensor data into an interpretable risk score remains proprietary and heterogeneous across manufacturers, which limits replication and comparison.(9)

Implementation, acceptability and adherence

The implementation axis asks whether the technologies are used, and for how long. Adherence to remote monitoring was reported as high in a cohort of patients at risk of diabetic foot ulcer who used temperature-based monitoring at home,(45)and the clinical stakes are considerable because a lower-extremity amputation occurs every 20 seconds as a complication of a diabetic foot ulcer.(45)A study of adherence to at-home foot temperature monitoring described a more guarded picture in which engagement declined over time and varied with baseline risk.(46)Feedback mechanisms may close that gap: context-aware conversational prompts were proposed to reinforce adherence to smart offloading, on the premise that adherence is a daily behavior subject to the same lapses as other self-care tasks and that objective tracking combined with timely prompts can reinforce it without additional clinic visits.(47)A multi-faceted digital health solution combining multimodal sensing, patient-facing biofeedback and remote monitoring was piloted as a case series.(48)Adoption determinants were synthesized in a systematic review of the Internet of Medical Things, which identified perceived usefulness, usability, cost and workflow integration as the recurring conditions for uptake.(49)A mixed-methods analysis of smart foot care technology described the relationship between knowledge and behavior among people with diabetes and highlighted technology adoption as a behavioral rather than purely technical problem.(50)Scoping reviews of self-care technologies and of smart digital technologies for ulcer prevention converged on the view that the interventions are acceptable but that evidence of sustained behavior change is thin.(51,52)

These reports converge on a consistent adoption profile: initial acceptance is generally high, sustained engagement is the weak point, and adherence improves when the device returns useful feedback and when it fits existing care routines.(45,49) They diverge on how much adherence is enough for clinical benefit, because the trials that demonstrated outcome effects relied on structured reminders and nurse follow-up that may not be reproducible at scale.(46)The gaps include the absence of cost-effectiveness analyses for most systems, limited evidence from low- and middle-income settings beyond single trials, and unresolved questions of data ownership and digital literacy among the populations that carry the highest ulcer burden.(52)For health services, the implication is that deployment budgets should weight training, feedback and workflow redesign as heavily as the device itself, because the behavioral and organizational components are what determine sustained use.(49)The reviews also note that most interventions were evaluated over weeks rather than the months or years over which ulcer risk accumulates, leaving long-term behavior change and its durability untested.(51)

Relations among the dimensions

Read together, the five axes describe a single intervention logic whose parts have matured at different rates. Telehealth supplies the care pathway through which the signals generated by smart insoles can be acted upon, and the trials of telemedical temperature monitoring illustrate this coupling: the insole or sock measures, the platform transmits, and the remote clinician instructs the patient to reduce weight-bearing.(2,18) Pressure sensing and temperature sensing are complementary rather than redundant, because pressure quantifies the mechanical cause of injury while temperature reflects the resulting inflammatory response; the devices that combine both therefore aim at prevention and early detection in the same unit.(29,38) Technical performance conditions every other dimension, since unreliable measurement undermines adherence and clinical trust, and cybersecurity risks scale with the connectivity that remote supervision requires.(10,44) Implementation, finally, is the axis through which all others either reach patients or remain pilot demonstrations: the best sensor or consultation model produces no benefit if patients stop using it or if clinics cannot absorb the data flow.(46,49) The relation that remains least established is the closed loop from detected signal to prevented ulcer, which would require the clinical endpoint studies that are still scarce across all dimensions. The overall trajectory is therefore toward integrated, multimodal platforms rather than single-channel devices, a shift already visible in combined pressure-temperature insoles and in multi-faceted digital health solutions.(39,48) From an evidence standpoint, the axes also differ in the level of proof they have reached: the temperature axis has randomized trials with recurrence outcomes, the telehealth axis has trials with healing outcomes, and the pressure and technical axes have mostly feasibility and accuracy evidence, an asymmetry that should guide the prioritization of future studies.

Table 1. Synthesis of the evidence by thematic axis.

Axis	Main finding	Representative evidence	Quality and limits
Telehealth models for diabetic foot care	Remote consultation and image follow-up can substitute for part of in-person care and shorten healing time	Two single-centre RCTs; retrospective cohort; realist evaluation	Small trials, observational cohorts, no multicentre confirmation
Smart insoles for plantar pressure	Sensing detects offloading adherence and classifies pressure patterns relevant to ulcer risk	Sensor-assisted RCT; monitoring platform; piezoresistive prototypes	Most systems at prototype stage, without ulcer endpoint trials
Smart insoles for plantar temperature	Continuous home temperature monitoring is feasible and extends classic thermometry trials	Telemedical RCT; thermography-guided RCT; device studies	Fixed versus continuous thresholds unresolved; no large modern ulcer trial
Technical performance and data processing	Pressure and temperature sensing are technically mature but lack standardized validation	Insole reviews; placement optimization; thermography framework	Laboratory accuracy exceeds in-shoe accuracy; cybersecurity concerns
Implementation, acceptability and adherence	Acceptance is high, sustained engagement is the weak point, feedback improves adherence	Adherence cohorts; adoption reviews; mixed-methods analysis	Few cost analyses; limited low-resource evidence
Relations among dimensions	Multimodal sensing plus telehealth forms a single prevention logic with unequal maturity	Telemedical temperature trials; combined pressure-temperature devices	Closed loop from signal to prevented ulcer not yet demonstrated

Note: RCT = randomized controlled trial. The number of studies per axis derives from the argument matrix.

DISCUSSION

The objective of this review was to synthesize the evidence on telepodiatry and smart insoles for remote monitoring of the diabetic foot, organized by thematic dimension. Taken together, the five axes describe a field that has advanced unevenly: the measurement technology and the care pathways are mature, the biological rationale is well supported, but the demonstration that remote monitoring prevents ulcers in routine care is still incomplete. The contribution of this synthesis is therefore to show where each dimension stands and where the links between dimensions remain missing.

For the telehealth dimension, the finding that remote diabetic foot care can shorten healing time is consistent with a systematic review and meta-analysis of randomized trials of telemedicine in diabetic foot ulcers, which reported overall benefit on wound outcomes, and with broader reviews of digital health in diabetes.(6,8) The result diverges from reviews that found small or inconsistent effects of mobile health on foot care behaviors, a difference explained by the outcome measured: wound healing responds to clinician-led remote treatment, whereas behavior change requires sustained patient engagement that simple reminders do not reliably produce.(53)Part of the disagreement across reviews also reflects study design, because meta-analyses that pooled randomized trials found benefit while syntheses that included nonrandomized mobile health programs found smaller effects, suggesting that the intensity of clinical supervision, not the technology itself, drives the result.(8,53) The qualitative evidence on rural and remote services adds an important caveat: telemedicine is only as effective as the workflow and infrastructure that surround it, a finding echoed by systematic reviews that identify access inequities rather than technology itself as the main barrier.(4,20)

In the pressure dimension, smart insoles address a limitation that prevention research has long recognized. The IWGDF prevention guideline and its supporting systematic review conclude that footwear and offloading reduce plantar pressure and ulceration, but that adherence to the prescribed device is often poor and difficult to verify.(3,14) Sensor-instrumented offloading converts that unmeasured adherence into an observable signal, which explains why the sensor-assisted trial and the SmartBoot platform focus on detecting device removal rather than on the pressure value itself.(22,23) The guideline context also clarifies why adherence monitoring matters: prevention is only effective if the prescribed footwear or cast is actually worn, and the gap between prescription and use has been a recurring explanation for failed prevention programs.(3)The divergence within this dimension is between adherence monitoring, which has reached clinical evaluation, and pressure classification, which remains largely at the prototype stage; the latter still needs to show that a detected pressure pattern can be acted upon to prevent an ulcer.(25)A related line of work extends the logic to shear, the tangential load that is harder to measure than normal pressure but may be equally damaging, as the shear-sensitive smart textile prototypes illustrate.(31)

The temperature dimension shows that the modern evidence reproduces and extends the classic trials. The early randomized trials of home thermometry showed that daily temperature monitoring with structured response reduced ulceration in high-risk patients, and the telemedical trial and the thermography-guided trial now test the same principle with connected devices and remote supervision.(2,12,13,32)The main scientific tension is the move from a fixed contralateral threshold to continuous monitoring: continuous data can detect inflammation earlier, but they also generate false alarms and measurement noise that daily single readings were designed to avoid.(36)The supporting prevention literature likewise frames temperature monitoring as an adjunct to structured foot care rather than a standalone intervention, which explains why the thermography-guided trial combined the measurement with nurse-led education.(14,32) The recurrence endpoint used in that trial is also the outcome that matters most to patients, because a first ulcer is the strongest predictor of a second.(3)Artificial-intelligence analyses of thermography images aim to resolve exactly this trade-off by learning the patterns that matter, although their diagnostic performance remains to be established prospectively.(54)The parallel literature on thermography and artificial intelligence makes the same point from the diagnostic side: algorithms classify thermal images with high reported accuracy, but the studies are dominated by small datasets and retrospective designs, so the transition to prospective screening remains the critical test.(54,55)

The technical dimension converges with a growing literature on computer vision and machine learning for the diabetic foot, which consistently reports high in silico accuracy for ulcer detection and segmentation but limited prospective validation.(7,55) The same pattern appears in the insole literature: hardware can resolve pressure and temperature, yet standardization of measurement protocols lags behind device development.(10)This matters for clinical adoption, because clinicians cannot interpret a signal whose calibration and quality control are not defined, and because networked devices introduce security risks that health systems are only beginning to address.(44)

Compared with earlier syntheses of the same terrain, this review finds a field that has shifted from feasibility toward early effectiveness. Previous reviews described wearable monitoring as promising but unproven and called for clinical studies; the randomized telemedical temperature trial and the sensor-assisted offloading trial now provide the first such studies, while leaving the prevention endpoint itself open.(7,10) That progression justifies cautious optimism, provided the next studies test the technologies under routine conditions rather than in the supervised settings that produced the early successes.(2)

The implementation dimension is where the field and the patient diverge. Patients generally

accept remote monitoring and express favorable attitudes toward telemedicine, a pattern documented among people with diabetes in Buenos Aires in an observational study that measured acceptability without foot-specific outcomes.(45,56) Sustained use, however, declines without feedback, and the determinants of adoption are behavioral and organizational rather than technical.(46,49) This explains a recurring pattern across the axes: the technologies that reached clinical effect were embedded in nurse-led or protocol-driven follow-up, which is precisely the component that is hardest to reproduce at scale. From a service perspective, the main operational risk is that remote monitoring increases rather than decreases clinical workload, because continuous data generate alerts that require triage and a system that flags every minor deviation will either be ignored or overwhelm the clinic; the realist evaluation of telemedicine makes this explicit by linking success to workflow design rather than to the technology itself.(18,20)

Read together, the dimensions also explain why single-channel solutions have underperformed. A pressure insole without a telehealth pathway cannot turn a detected signal into a clinical action, and a temperature sock without feedback loses patient engagement; the studies that report clinical benefit are those that joined measurement, transmission and response in one protocol.(2,32) This integration, rather than any individual sensor, appears to be the active ingredient, and it is the component that most published prototypes do not yet test.

This review has limitations. First, the search favored large bibliographic databases and English-language reporting, so work published in smaller or regional venues and in other languages may be underrepresented; a complementary search of regional literature would reduce that bias. Second, selection was narrative rather than exhaustive, and no formal risk-of-bias instrument was applied to individual studies, which limits the confidence with which the strength of evidence can be graded. Third, publication bias is plausible in a field dominated by prototype and pilot reports, because negative device results are less likely to be published than positive ones. Fourth, cost and equity outcomes were rarely reported, so the economic case could not be assessed; future syntheses should extract cost and access data systematically. Fifth, several included studies were single-arm or laboratory validations whose results may not generalize to daily wear, so the synthesis leaned on design and context rather than on pooled effect sizes; systematic extraction with a risk-of-bias tool would strengthen future updates.

The practical implications follow from these findings. Clinics can begin with the components that already have clinical support, namely structured remote wound review and telemedical temperature monitoring with a defined response protocol, and treat smart insoles primarily as adherence and self-management tools rather than as diagnostic devices.(2,22) Podiatrists are well placed to lead this integration, because the interpretation of pressure, temperature and wound images belongs to the same clinical reasoning used in face-to-face foot assessment.(11)The research agenda should prioritize pragmatic trials with ulceration and recurrence as primary endpoints, consensus validation protocols for insole measurement, and studies in the low-resource settings that carry the highest burden.(4,10) Regulators and purchasers would benefit from a minimum reporting standard for insole studies covering sensor type, placement, calibration, wear time and data handling, so that evidence from different devices becomes comparable.(9,10)

CONCLUSIONS

Telehealth models for diabetic foot care can shorten healing time and maintain surveillance at a distance, although the supporting trials remain single-centre. Smart insoles for plantar pressure monitoring reliably detect offloading adherence and classify pressure patterns, but they have not yet shown an effect on ulcer prevention. Smart insoles and footwear for plantar temperature monitoring rest on the strongest clinical rationale and reproduce classic thermometry findings with modern devices, pending a large pragmatic trial. The technical performance of the sensing hardware is adequate, while standardized validation, data quality and cybersecurity remain open. Implementation succeeds when remote monitoring is supervised, returns feedback and fits existing workflows, and the relations among the dimensions point to multimodal sensing combined with telepodiatry as the most coherent path forward.

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