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The reported external traumas among people with diabetes-related foot ulcers and their outcomes: A systematic review of case reports

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Abstract

The objective of this systematic review was to collate evidence published in case reports on the reported origins of external traumas that contribute to the development of diabetic foot ulcers and their outcomes. The review also aimed to suggest reporting criteria for external traumas contributing to the development of diabetic foot ulcers. The search strategy led to the identification of 1224 articles across six electronic databases. Additional articles were also sourced from other electronic platforms (Google scholar) and the reference lists of the included case reports. Ninety-four articles met the inclusion criteria and were published between 1989 and 2020. The included case reports were independently assessed for methodological quality using a Joanna Briggs Institute (JBI) checklist. Following the verbatim extraction of data, the JBI three steps approach to "meta-aggregation" for managing qualitative data was used to synthesise the data on external traumas that contributed to the development of foot ulcers along with the reported outcome. Information on the included case report characteristics was also extracted. The case reports included 155 patients. Average age was 57.2 years with a range from 17 to 86 years. External traumas were mainly experienced in the domestic setting and were categorised into two main categories, mechanical trauma (n = 87, 60%) or burns (n = 58, 40%). The most frequently reported origins of external trauma were contact with a hot surface, animal bites, friction, and puncture wounds. Although healing was the most frequent outcome, a prolonged time was recorded for the ulcers to heal highlighting the importance of prevention. Prevention might not eradicate origins of external trauma 100%, showing the importance of patient and/or family role in monitoring domestic risks, early detection of ulcer and seeking immediate professional care. Foot ulcers need to be reported against standardised criteria considering local characteristics of the ulcer and the individual's general profile.

KEYWORDS

case reports, diabetes, diabetic foot, trauma, ulcers

Key messages

- traumas contributing to the development of diabetic foot ulcers frequently occur in the home environment and they extend from the bed to recreational activities
- although healing is the most likely outcome to happen, a prolonged time is required to achieve such an outcome that might extend to months and/or even years. In certain circumstances, the outcome might develop to amputation. Examples of such certain circumstances include accidental recognition of the ulcer occurrence, self-treatment prior to seeking professional advice, experiencing more than one ulcer at the same time, and developing recurrent ulcers, uncontrolled diabetes, and the presence of comorbidities among other circumstances
- given that the cultural context and/or the socio-demographic profile determine/s the type of trauma contributing to foot ulcers, preventive programs need to be contextualised to alert those with diabetes and their families/caregivers to possible risks that they can avoid within the local context. Indeed, minor traumas might not be avoidable 100%, revealing the importance of early detection of ulcer and seeking immediate professional care where family can help in monitoring domestic risks
- research is required to find risks within the local context where foot ulcers need to be reported against standardised criteria considering local characteristics of the ulcer and the patient general profile (demographics, health, social and economic). The ulcer local characteristics include origins of the external trauma, time of the incident, mechanism of the incident/ulcer development, how, who and when the ulcer was discovered, and initial treatment sought.

1 | INTRODUCTION

Diabetic foot ulcer prevention is a global challenge not only because of the constant growth in the number of people diagnosed with diabetes but because the recurrence of foot ulcers is higher post primary presentation.[1] It is estimated that nearly one-fifth to one-third of adults diagnosed with diabetes experience a foot ulcer at some point in their lifetime.[1,2] The aetiology of diabetic foot ulcers is multifactorial and includes a combination of intrinsic and extrinsic factors.[3,4] The intrinsic factors are long-term diabetes complications, and it is well-established in the literature that these complications (peripheral neuropathy and foot deformity) are primary contributing factors.[2,4] Peripheral vascular disease is a factor complicating foot ulcers, delaying healing and increasing the chance of infection because of poor blood supply.[5]

Indeed, reducing the incidence of diabetes complications is considered the corner stone for diabetic foot ulcer prevention in that intact peripheral sensations will enable the discovery of ulcers in the initial stages, and help seeking behaviour.[6] Similarly, the prevention of foot deformities will reduce the likelihood of creating pressure points against which repetitive pressure might trigger an ulcer.[6] In brief, preventing diabetes complications will enable the prompt discovery of ulcers triggered by extrinsic factors (trauma) and/or avoiding sources of external trauma. For example, the International Working Group on the Diabetic Foot (IWGDF) recommend measures such as foot screening and preventive footwear among others.[7] Identifying possible causes of external traumas is the initial step in reducing the risk of developing a foot ulcer. In a recent integrative review of primary research publications the causes of foot ulcer development following trauma among people with diabetes were examined.[8] The review suggested that foot care prevention programs can highlight the origins of external traumas as examples to alert people with diabetes to possible risks that they can avoid. It was noted that the reported traumas were mainly in the patient's home environment, and reflected the cultural context . The traumas identified were mostly described as an aside of the included articles with limited details on the context of

the incident (how it happened). Indeed, the availability of information on context would enable prevention programs to provide more detailed examples (of possible origins of trauma) and scenarios. A decision was made to systematically review case report publications of foot ulcers where the contribution of external traumas was described. The decision to review case reports rather than qualitative studies was that the integrative review cited above included qualitative publications and the extensive search revealed only two studies. Although case reports are a form of anecdotal evidence, they contain detailed information on an individual patient including the context of the incident.[9] Reviewing relevant case reports would not only expand on evidence generated in the integrative review but would also highlight the context in which external traumas present. This level of detail will support the development of criteria for the report of external traumas that contribute to the development of foot ulcers and address a recommendation of the integrative review. The aims of the review were to report on external traumas that contributed to the development of diabetic foot ulcers and their outcomes as reported in case reports. The review also aimed to suggest reporting criteria for external traumas contributing to the development of diabetic foot ulcers drawing on the detail presented in the case reports.

2 | METHODS

2.1 | Design

Using the JBI (Joanna Briggs Institute) framework,[10] a systematic review approach was employed to examine case reports documenting the origin of external traumas contributing to the development of foot ulcers among adults diagnosed with diabetes.

2.2 | Search strategy

The review team developed the search strategy in light of a logic grid and PICoS' framework; P (Population), people with diabetes; I(Interest), trauma, Co (Context) foot ulcers; and S (Study type) case reports (Data S1). The second author implemented the search strategy and, on weekly basis, discussed the search progress with the review team that made decisions as required. A three-steps search strategy was employed to locate case reports required for the purpose of this systematic review. In line with the JBI approach, an initial limited search of CINAHL was undertaken using MeSH terms joined with keywords, in combination with Boolean operators [AND, OR].[11] The MeSH terms included Diabetic foot, diabetes, and case reports. A second search was conducted, using Mesh terms and keywords in the title, abstract and index terms of identified articles across all included databases, (Medline, CINAHL, Scopus, Proquest Central [Health and Medical, British Nursing Database, Nursing and Allied Health Database], Embase, and Web of Science). The text words utilised were wounds, injur*, trauma, burn*, accident*, needle-stick injury, animal bites, rodent bites, blisters, burns, puncture wounds, footwear, Diabetic holiday foot syndrome, home, thermal injuries, walking, The Haj (Muslim Pilgrimage) Pilgrimage, hot appliances, household appliances, tacks. Thirdly, we searched the reference list of all identified reports for additional case reports. No date limit was applied but case reports had to be full text, peer-reviewed, and published in academic journals in English. The searches included "Apply related words," "search within the full text of the articles" and "Apply equivalent subjects." The searches lasted for 3 months from February to May 2018 and were updated in 2019 and 2020.[11]

2.3 | Inclusion and exclusion criteria

Our primary inclusion criterion was a case report or a letter to the Editor that focussed on foot ulcers as experienced by an adult with diabetes and reported an external trauma as a triggering factor. Case reports were excluded if they did not identify how the foot ulcer occurred. Following the removal of duplicates, the search identified 1224 articles (Figure 1). One hundred and eighteen full text papers were assessed for eligibility, of which 24 were excluded at the full text level. There were four reasons for exclusion (Data S2), first, not specifying how the ulcer occurred (n = 21). Second, the case report (n = 1) was a composite teaching scenario (a fictitious teaching example), third, the patient did not have diabetes in another case report (n = 1) and fourth, there was no involvement of external trauma instead ankle inversion was reported as the trigger in the ulcer development. Within this, if the article contained more than one case, data extraction was limited to those having diabetes with external trauma contributing to ulcers.[12-14] The remaining 94 case reports were included as they reported events that identified the origin of external trauma contributing to a foot ulcer for a person living with diabetes (Figure 1).

2.4 | Assessment of methodological quality

Two independent reviewers (the first and the third author with the second author acting as the common

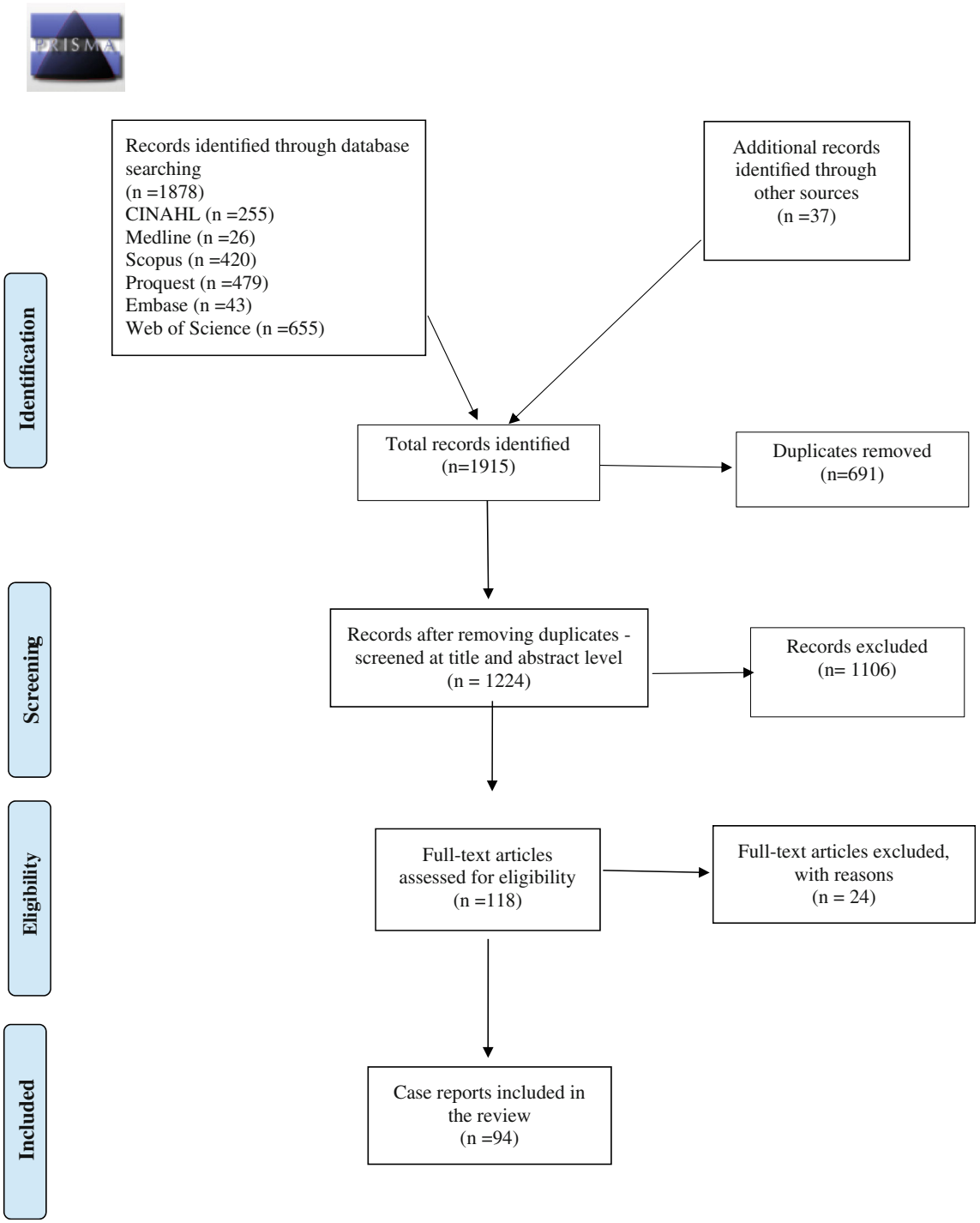

FIGURE 1 PRISMA flow diagram from Moher et al.[117]

link) assessed the identified articles for methodological quality using the Joanna Briggs Institute Critical Appraisal Checklist for Case Reports.[15] The checklist included eight questions with four possible options (Yes, No, Unclear, not applicable) (Data S3). Any disagreements that arose between the reviewers were resolved through discussion, or with a third reviewer.

Considering previous reviews that used the JBI approach, the methodological quality was configured from two perspectives.[16] The first perspective included the overall quality of each individual case report where the answers given to the appraisal checklist questions were quantified by assigning a score of 3, 2,1, or 0 to the answer "Yes," "Unclear," "Not applicable" or "No,"

respectively." The given scores were summed (the maximum expected score for each case report was "24"), and then each case report was classed as "high quality" (≥19), "moderate quality" (14-18) or "low quality" (≤13). The second perspective on quality appraisal was the percentage of the questions that were answered as "Yes."[16]

2.5 | Data collection

A tool was designed to extract data. The second author extracted the data verbatim, and the first author checked the accuracy of extraction by examining the tables against the included articles. The process included descriptive data "verbatim" on the origin of the external trauma and the outcome of the ulcer. Patient demographics (age, gender, their country) and health profile (type and duration of diabetes and presence of other medical conditions and setting of treatment [hospital or community]) were extracted. The human development index of the countries where the included case reports originated were documented.[17] The human development index covers three aspects (health, knowledge and standard of living) of human development of a country's average achievements as judged by the United Nations Development Program (UNDP).[17]

2.6 | Data synthesis

Data on the origins of the external trauma and patient outcomes were synthesised and quantified. The JBI approach (meta-aggregation) for managing qualitative evidence was used to synthesise the data.[18] Meta-aggregation is a three-step approach where the first step included extracting (from all included case reports) all information on external traumas contributing to foot ulcers. Then, categories were developed for external traumas that were sufficiently similar in terms of their nature and the categories were grouped (step three) according to the type of trauma.

3 | RESULTS

3.1 | Case report profile

The included case reports were published between 1989 and 2020. Most case reports (n = 71, 76%) were from Very High Human Development Index countries followed by high (n = 14, 15%), medium (n = 7, 7%) and low (n = 2, 2%) Human Development Index countries, respectively. In most case reports (n = 80%, 85%), patients were treated in urban hospital settings (Data S4). In nine (10%) case reports, patients were hospitalised after initial community treatment including rural sites as was the case of a report from a high Human Development Index country.[19] In five (5%) case reports, patients were initially treated in urban hospitals and completed the treatment in the community. In two case reports, the setting was unclear.[20,21] In 12 (13%) case reports, patients were treated in urban community settings.

The majority (n = 77, 82%) of the included case reports were assessed as being of high quality methodologically, and only two (2%) low quality. The answer "Yes" was given to seven, out of the eight of the critical appraisal questions of 74 case reports (78.7%), (Data S3).

3.2 | Patient profile

The included case reports documented external traumas that contributed to the development of foot ulcers experienced by 155 patients. In one case report (n = 7 patients), it was reported that the external traumas aggravated pre-existing ulcers for two patients.[22] Nearly three-quarters (n = 115, 74.2%) of patients were males and 26 (16.8%) females. Gender was not reported for 14 patients (Data S4). Age was reported for 128 patients and ranged from 17 years to 86 years (SD 12.4 years, mean 57.2 years). In one paper that documented seven cases, age was reported as a range from 36 to 68 years.[22] Type of diabetes was not reported for 70 patients. More than one-third (n = 66) had type 2 diabetes and 12.3% (n = 19) had type 1 diabetes. Duration of diabetes was not reported for 81 patients (53%) and ranged from "diagnosed on admission" to 33 years for the remainder. The majority of patients were diagnosed with comorbidities (n = 110, 71%) (Data S4).

3.3 | Reported traumas

One hundred and forty-six reports of 81 different external traumas were reported as contributing to foot ulcers (Table 1). Interestingly, the identified external traumas were mainly minor and occurred during the conduct of activities of daily living including sleeping, walking, swimming, self-care practices or recreational activities. Less than 10% of reports (n = 13 reports) were unforeseeable accidents and therefore not preventable. These included being attacked on a beach by a crow, accidentally kicking a locker, treading on a clout nail which pierced a boot, falling off a water-ski, foot pierced by a drill and being struck by lightning.

Categorising the extracted information by the nature of trauma resulted into 11 categories (Figure 2) that were

TABLE 1 Reported Traumas

Type of trauma	Nature of trauma	Reported trauma/precipitating event
Mechanical	Animal bites/stings	Crow attacked foot and leg with beak and talons[105]
		Fish sting while walking barefoot in the sea[30]
		Mouse bites whilst asleep[a21]
		Rat bites during sleep[19,20,36,40,52,58,59,63,94]
		Pet dog chewed all toes over a 4-month period[a] 4 independent occasions[25]
		Pet dog chewed right hallux, right second and third toes[a] two independent occasions[80]
		Pet dog chewed left hallux[87]
		Pet cat chewed toes of right foot[51]
	Friction	Badly worn orthoses[66]
		Deep neuropathic ulcer from shoe caused Achilles tendon to rupture[90]
		Friction from beach shoes[26]
		Friction from plastic beach shoes[a95]
		Ill-fitting shoes and socks[81]
		Ill-fitting shoes on the sole of foot near the heel[47]
		Inappropriate footwear and self-treatment without using medical products- three independent ulcers[56]
		New hiking boots[84]
		New shoes[42,104]
		New Slippers[37]
		Plaster cast for a fracture[14,80]
		Plaster of Paris cast[34]
		Removed callus with over-the-counter adhesive plaster[68]
		Rolled edge of compression bandage[48]
		Sandal strap caused wound[26]
		Worn lining of surgical shoes caused blisters on toes[100]
	Blunt force trauma	Bruising from car accident[35]
		Accidentally kicked a locker[44]
		Car keys had fallen into shoe avulsing toe nail[76]
		Bumped foot into a cabinet[79]
		Barefoot walking on rough surface[a26]
		Puncture injury while walking barefoot in her home- tried home remedies for a fortnight[101]
		Developed blisters after swimming in a pool[b22]
		Damaged foot on swimming pool floor[a22]
		Skin damaged while detaching surgical tape and a wound developed[49]
		Traffic accident causing metatarsal fractures and plantar tissue defect[118]
		Accidental fall damaged deep tissues of left foot followed by non-effective self-treatment[121]
	Pressure ulcer	Immobilisation in hospital[38,83]
		Immobilisation after surgery[13,62]
	Puncture wound	Cut by strap on plastic beach shoes[95]
		Foot pierced by drill[99]
		Metal nail embedded in toe[61]

(Continues)

TABLE 1 (Continued)

Type of trauma	Nature of trauma	Reported trauma/precipitating event
		Metal nail penetrated shoe while gardening[77]
		Patient trod on two toothpicks[71]
		Piece of shell walking barefoot on beach[54]
		Puncture wound to the foot while working in his yard whilst wearing slippers[77]
		Self-injury wound, to relieve severe pruritus by piercing skin with sharp implements[102]
		Small screw embedded in slipper[76]
		Thumb tack embedded in heel[96]
		Thumb tack embedded in shoe[97]
		Thumb tack embedded in toe whilst walking barefoot[96]
		Tip of hypodermic needle penetrated third toe of right foot causing swelling and cellulitis[74]
		Trod on a clout nail which pierced boot[a119]
		Trod on a metal nail[60]
		Trod on a metal nail that punctured shoe[60]
		Walking barefoot and trod on a toothpick[67]
	Unusual activity	Officiated at 5 softball games in one day and subsequently developed cellulitis and ulceration[78]
		Increased walking activity on the day ulcer appeared[75]
		Increased exercise on holiday[65]
		Fell off a water ski and dragged by ski binding on the foot in water causing abrasion, oedema and bruising[88]
		Developed a blister on the planter aspect the first right toe after a walking holiday[106]
Burns	Chemical burns	Exposure to undiluted Dettol split on shoe[45]
		Urine burn on foot due to incontinence[43]
		Applied raw crushed garlic to feet to self-treat neuropathy[57]
		Chinese herbal medicine patches for pain relief on ischaemic toe[120]
	Contact burns	Walking barefoot on hot street[c27]
		Barefoot on hot concrete pavement[28]
		Walked 1 km barefoot to the Temple on a hot day[98]
		Walking barefoot on a sandy beach[a46,95]
		Walking bare foot on a beach[95]
		walking on the hot sand[122]
		Walked barefoot on hot poolside tiles[91]
		Walked barefoot on cobblestones[70]
		Walking on hot flag stones[a,b26,95]
		strolling on a scorching ceramic pavement[122]
		Foot spa without water[a82]
		Long contact with a hot plate[33]
		Put foot on Electric heating pad[29]
		Put foot on a hot radiator[107]
		Gel-filled microwave-heated bag to relieve foot coldness[89]
		Slept with hot water bottle under left foot to warm it[55]

TABLE 1 (Continued)

Type of trauma	Nature of trauma	Reported trauma/precipitating event
		Slept with hot water bottle between feet[55]
		Hot water bottle[69]
		Hot water bottle to warm feet[72]
		Contact with microwaved "wheat-filled" bag[89,103]
		Metal portion of an electric massager overheated and burnt foot[98]
	Scalds	Put foot into hot water[12]
		Immersion into a hot foot bath/ft spa[b41]
		Immersed foot into hot water[64]
		Immersed foot into pail of boiling water[64]
		Soaked left foot in a basin of hot water[98]
		Burnt left foot with hot water[98]
		Hot water steam therapy to cure recent onset foot drop[64]
		Scald after a foot bath[41]
		Poured very hot water over feet[98]
		Sauna and steam shower[93]
	Radiant burns	Hair dryer used to dry wet cast[50]
		Infrared massaging device[92]
		Floor heater of car[31]
		Exposure to fan heater[33]
		Radiant heat from fire making grape molasses[73]
	Electrical	Struck by lightning causing burn on hands and foot[53]

[a]In the same article, this trauma was cited as a contributing factor to foot ulcer experienced by two patients.
[b]In the same article, this trauma was cited as a contributing factor to foot ulcer experienced by three patients.
[c]In the same article, this trauma was cited as a contributing factor to foot ulcer experienced by eight patients.

grouped, by the type of trauma, into either mechanical trauma (n = 87, 60%) or burns (n = 58, 40%) (Table 1). Given that some patients experienced more than one trauma at the same time, the total number of identified traumas was greater than the number included in the review. The group mechanical trauma was made up of six categories including animal bites and stings, friction, blunt force trauma, pressure ulcer, puncture wound and unusual activities. The category of "burns" included five categories namely chemical burns, contact with a hot surface, scalds, radiant burns, and electrical burns.

The most frequently cited trauma was contact with a hot surface (n = 36, 24.8%) followed by animal bites and stings (n = 25, 17.2%), friction (n = 20, 13.8%) and closely followed by puncture wounds (n = 18, 12.4%) (Figure 2). The least frequent category was electrical burns (n = 1, 0.7%) preceded by chemical burns and pressure ulcers (n = 4, 2.8%) and radiant burns and unusual activities (n = 5, 3.4% for each category) (Figure 2). Detailed examination of the reports within each category showed that contact with a hot surface resulted from walking bare foot on a hot surface that could be at home, religious places or at recreational sites. In other words, the hot surface could be the street, pavement, concrete, tiles, or a sandy beach. Contact with a hot surface also included using the feet to support a hot object "plate" or self-care practices that aimed to warm cold feet using a hot application (hot water bottle, overheated electric massager, electric heating pad, hot radiator among others). Indeed, attempts to warm cold feet were also found in the category "scald" (n = 12, 8.3%) including soaking/immersing the foot into a hot water/spa, using steam therapy or taking a sauna.

Within the context of foot warming, the category radiant burns included using a hair dryer to dry a wet cast, heat from a car floor/fan heater and heat from an infrared massaging device. Additional foot care practices were found in other categories, for instance (in the category chemical burns), crushed garlic was applied to treat neuropathy and herbal patches were applied to relieve pain on an ischemic toe.[57] Further examples of foot care practices included a blunt trauma caused by detaching

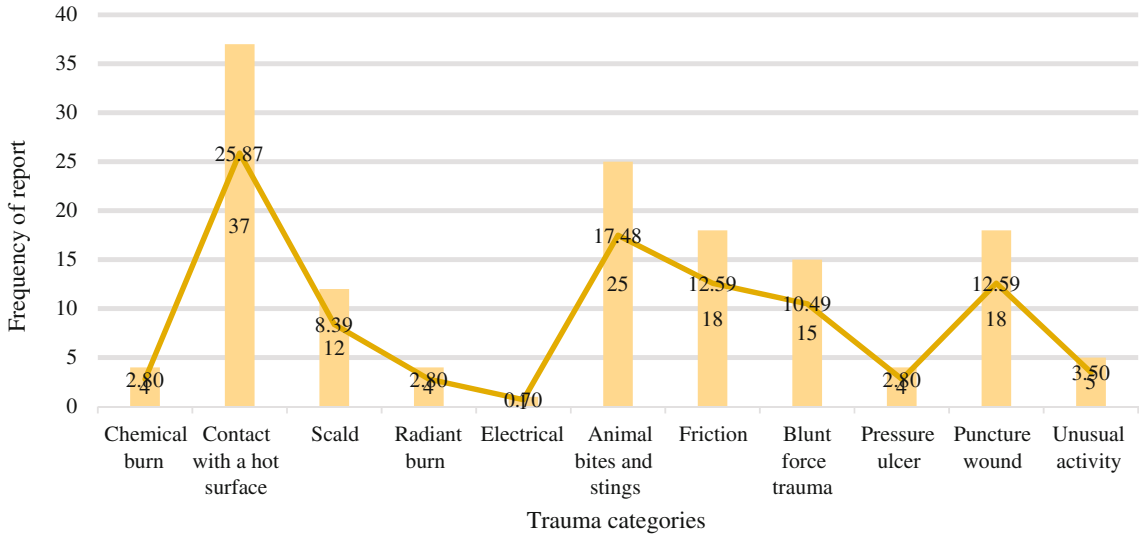

FIGURE 2 Trauma categories and frequency of report

surgical tape,[49] a friction trauma that resulted from the removal of a callus with an over-the-counter application,[68] and a puncture wound resulting from the use of a sharp implement that pierced the skin to relieve severe pruritus.[102] In review, traumas resulting from foot self-care practices were evident across different categories. Indeed, foot care practices included external traumas related to the actions/advice of healthcare professionals (6.7%, n = 9). Actions/advice of healthcare professionals included a radiant burn from drying a wet plaster cast with a hair dryer, another example included friction from compression stockings or Plaster of Paris casts.[34,48,50,80]

Further examination of the identified categories showed that external traumas varied by cultural context and/or geographical location. For example, pets were the source of external trauma in very high Human Development Index countries (mainly the United States of America [USA] and the United Kingdom [UK]) and rat/mouse bites were a named cause of trauma in very high and high Human Development Index countries and urban areas of medium and low Human Development Index countries. It was noted that animal bites occurred mainly during sleep. The identified categories comprised additional origins of external trauma contributing to foot ulcers. For example, chemical burns resulted from incontinence when urine splashed on the foot or resulted from accidental exposure to undiluted Dettol on a shoe.[45] Within the category friction, footwear was cited as a common origin of external trauma. The footwear-related traumas identified ranged from wearing new shoes,[42] ill-fitting shoes,[47] or slippers to badly worn orthoses.[37,66] In the category, blunt force traumas, the external traumas identified ranged from barefoot walking on a rough surface, swimming and traffic accidents. Other self-induced mechanical injuries included increased activity (walking more than usual). In the category, puncture wounds, the external traumas identified were mainly stepping, either barefoot or in shoes, on sharp objects, for example, a toothpick, needle, metal nail, tack, screw, or piece of shell.[54,67,71,74,76] Unusual activities that led to trauma included prolonged walking during holidays, playing five softball games in 1 day, and a water ski binding rubbing on the foot.[75,78,88]

3.4 | Ulcer related outcomes

Out of the 94 reviewed case reports, outcomes were reported in 80 (85%), and ranged from healing, developing complications and amputation to death. Healing of the ulcer was reported for 90 patients. A range of terms were reported that were aggregated into three main groups including healing (n = 33, 36.7%), healed (n = 26, 28.9%) and complete healing (n = 28, 31.1%). In three patients, the ulcers were still healing at the time of publication. Table 2 shows the outcomes as reported (verbatim) in the included articles. Failure to heal reported for six patients. Two patients developed complications including osteomyelitis[91] and spontaneous calcaneus fracture.[33]

There were 35 amputations reported as a direct result of the ulcer caused by an external trauma. Twenty-one were below the ankle and eight amputations were above the ankle. The level of amputation was not reported for six patients. For the purpose of this systematic review, amputation was considered one outcome even if the patient underwent more than one procedure [amputation] for different ulcers.[25,63] In one case report, the

TABLE 2 Ulcer outcomes

Authors	No. of cases	Reported time to outcome	Outcome
Ahmed et al. (2013)[45]	1	10 mo	Healing
Al-Qattan (2000)[27]	8	2-3 mo (n = 5) 21 d (n = 2) NR (n = 1)	Healed (n = 5) Skin grafting, discharge, and mobilisation (n = 2) Minor amputation NR (n = 1)
Al-Zacko and Mohammad (2017)[28]	2	45 d (n = 1) 5 wk (n = 1)	Recovered with acceptable local findings (n = 1) Healed (n = 1)
Baghaei et al. (2020)[56]	1	15 mo	Completely improved
Balakrishnan et al. (1995)[12]	2	NR (n = 2)	NR (n = 2)
Ballard and Cooper (1994)[25]	1	NR[a]	Minor amputation
Beshyah (2020)[122]	2	12 wk (n = 1) 1, 6 and 12 wk (n = 1)[a]	Entirely healed (n = 2)
Bhattacharyya and Webb (2001)[74]	1	NR	NR
Bill et al. (1994)[29]	1	NR	Healed by contraction
Brereton (2013)[43]	1	6 wk	Fully healed
Cadogan (2008)[47]	1	7 mo	Completely healed
Chai et al. (2020)[121]	1	60 d[d]	Completely healed
Chan et al. (2014)[30]	1	Discharged day 11	NR
Chapman (2009)[34]	1	17 mo	Continuing to heal
Cooles and Paul (1989)[19]	4	2 wk[b] (n = 3) 17 d (n = 1)	Healed satisfactorily (n = 2) Healed (n = 1) Major amputation (n = 1)
Cuschieri et al. (2013)[31]	1	25 wk	Complete healing
Das and Agarwal (1991)[32]	1	Discharge after 10 d	Healed
Delahoussaye-Shields et al. (2011)[54]	NR	NR	NR
Delshad et al. (2016)[35]	1	7 wk	Fully closed
Dietz et al. (2004)[57]	1	6 wk	lesions resolved
Dijkstra et al. (1997)[41]	6[c]	2-27 mo	Failed to heal (n = 1) Healed (n = 3) Amputation (n = 5)
Donate et al. (2008)[63]	1	NR	Major amputations (bilateral)
Dorfman et al. (2014)[102]	1	4 wk	Minor amputation
Edo et al. (2010)[36]	1	57 d	Healed
Evers (2011)[38]	1	7 wk	Fully healed
Ezeani et al. (2013)[40]	1	49 d	Healed ulcers
Frykberg et al. (2015)[44]	1	6 mo	Minor amputation
Gaztelu Valdés et al. (2002)[46]	1	4 wk	Fully healed
Haridass et al. (2015)[22]	7	22 d	Minor amputation (n = 2) Major amputation (n = 1) Unhealed (n = 2)
Harkin (2010)[107]	1[a]	41 d	progressed to wound healing
Haycocks et al. (2011)[66]	1	13 wk	Healed

(Continues)

TABLE 2 (Continued)

Authors	No. of cases	Reported time to outcome	Outcome
Henderson et al. (2013)[50]	1	21 d	Minor amputation
Hoffman and Donovan (2013)[51]	1	NR	Minor amputation
Hopkinson et al. (2013)[37]	1	NR	NR
Ibrahim et al. (2015)[52]	1	6 wk	Healing well
Jagjivan et al. (2004)[53]	1	NR	Ulcers are healing
Jarial et al. (2016)[20]	1	NR	NR
Jose et al. (2005)[55]	2	19 d (n=1) NR (n = 1)	Skin graft taken well (n = 1) Still under review at publication (n = 1)
Kalra et al. (2006a)[58]	8	1-2 wk	Good healing (n = 8)
Kalra et al. (2006b)[59]	1	NR	NR
Kennedy and Van Zant (2006)[78]	1[a]	9 and 12-13 wk[a]	Completely healed
Laughlin et al. (1997)[60]	2	NR (n = 2)	NR (n = 1) Major amputation (n = 1)
Leonard and O'Donnell (2000)[61]	1	Prolonged hospitalisation	Minor amputation
Lodge et al. (2006)62	1	9 mo	Amputation
Loh and Tan (2014)[64]	3	7 wk (n = 1) 16 d (n = 1) 10 wk (n = 1)	NR (n = 1) fully healed (n = 1) Minor amputation (n = 1)
Lott et al. (2005)[75]	1	20 mo (63 d after total contact casting [TCC])	Full epithelisation
Matsumura et al. (1998)[33]	2	3 mo (n = 1) 10 mo (n = 1)	Discharged walking without assistance (n = 1) Developed avulsion type spontaneous calcaneus fracture (n = 1)
McConville and Lee (2004)[69]	1	108 d	Minor amputation
McConville (2006)[65]	1	13 d	Blisters resolved totally
McConville and Kingston (2008)[42]	1	NR	Healed
McDaid and Collier (2010)[91]	1	6 wk	Right foot ulcer-fully healed Left foot ulcer-clinical signs of osteomyelitis
Mehrannia et al. (2014)[70]	1	8 month-follow up period	Satisfactory healing
Melton et al. (2015)[67]		3 wk	Full recovery from the injury/infection
Mensa et al. (2017)[80]	1[a]	2 mo NR	Heal by secondary intention Minor amputation
Mohamed et al. (2014)[72]	1	7 wk	Fully healed
Mozer et al. (2006)[88]	1	3 mo	Healing
Mutluoğlu and Uzun (2009)[73]	1	NR	Fully healed
Nag et al. (2004)[76]	2	NR (n = 2)	Fully healed (n = 1) NR (n = 1)
Naraynsingh et al. (2011)[77]	2	6 wk (n = 1) 8 wk (n = 1)	Fully healed (n = 1) still healing (n = 1)

TABLE 2 (Continued)

Authors	No. of cases	Reported time to outcome	Outcome
Nather et al. (2007)[14]	1	34 d	Healed
Neto et al. (2012)[99]	1	2 mo and 25 d	Transfer to another hospital with recommendation for amputation
Olivieri et al. (2015)[79]	1	8 d	Healing (n = 1)
Ovadia et al. (2005)[68]	1	4 d	Healing (n = 1)
Ovesen and Wildfang (1990)[82]	2	6 w k (n = 1) 7 mo (n = 1)	Healing (n = 1) Major amputation (n = 1)
Pickin et al. (2008)[26]	7	3 wk (n = 3) 4 wk (n = 3) 5 mo (n = 1)	Healing (n = 3) Healing (n = 3) Healing (n = 1)
Pinto (2011)[83]	1	7 mo	Complete closure
Popoola (2003)[84]	1	7 y	Major amputation
Putz et al. (2008)[85]	2	3 mo (n = 1) 6 mo (n = 1)	Minor amputation (n = 1) Healing (n = 1)
Ramanujam and Zgonis (2012)[86]	1	18 wk	Minor amputation
Rawe and Vlahovic (2012)[13]	1	6 wk	Still healing
Robertson et al. (2014)[48]	1	2 mo	Full healing
Rogers and Bevilacqua (2011)[87]	1	NR	Minor amputation
Rowlands et al. (2010)[89]	2	14 wk (n = 1) wk 33 (n = 1)	Healed (n = 2)
Saleem et al. (2010)[90]	1	NR	Discharged home with ankle joint splint with regular follow up in the clinic
Salmanoğlu and Önem (2014)[49]	1	NR	Fast healing
Sever et al. (2011)[92]	1	NR	NR
Shah et al. (2007)[21]	2	NR	NR
Shankhdhar et al. (2011)[101]	1	14 wk	Ulcer healed
Shen et al. (2016)[71]	1	8 mo	Healed
Shridhar (1992)[94]	1	NR	Healed
Stanaway et al. (2001)[95]	10[a]	Several mo (n = 2) NR[a] 28 d (n = 1) NR (n = 7)	Still open (n = 1) Major amputation Full healing (n = 1) Complete healing (n = 1) NR (n = 7)
Teelucksingh and Naraynsingh (1997)[96]	1	NR	NR
Teelucksingh and Naraynsingh (2010)[97]	1	6 wk	Healed completely
Thng et al. (1999)[98]	5	481/2 mo (n = 1) 43 d (n = 1) 34 d (n = 1) NR (n = 1) 6 mo (n = 1)	Healing (n = 1) NR (n = 1) Infection eradicated (n = 1) NR (n = 1) Still ulcerated (n = 1)
Thomas (2008)[100]	1	5 mo	Healed nicely

(Continues)

TABLE 2 (Continued)

Authors	No. of cases	Reported time to outcome	Outcome
Thornton et al. (2002)[103]	1	NR	Partial healing
Tobalem and Uçkay (2013)[104]	1	3 y	The infection resolved
Tripathi and Erdmann (2008)[105]	1	52 d	Full healing
Turns (2012)[106]	1	15 wk	Minor amputation
Vaienti et al. (2010)[118]	1	82 d	Began to walk wearing normal shoes
Vidyarthi et al. (2010)[93]	1	5 wk	Healing was occurring
Williams et al. (2004)[119]	2	2 mo (n = 1) 6 wk (n = 1)	Complete healing (n = 1) Minor amputation (n = 1)
Wong et al. (2002)[120]	1	NR	NR
Zheng et al. (2014)[81]	1	16 mo	Minor amputation

Note: Reported time to outcome was copied verbatim from the included articles.
[a]This patient experienced more than one ulcer that might be at independent occasions- in both feet.
[b]Period pf receiving treatment prior hospitalisation.
[c]The total n of outcomes is more than six because some patients had more than one ulcer. Two patients developed recurrent foot ulcers (burns) after 27 and 43 months, but the outcome was not reported.
[d]The patient discovered the ulcer 15 days after the incident, tried self-treatment (for 5 days).

patient was transferred to another facility for amputation.[99] Only one report mentioned death as an outcome from the ulcer, in which the 63 year old patient underwent a below the knee amputation but developed septicaemia and then shock.[41] In some cases, the reported outcome was not related to the ulcer rather a comment on the procedure and or patient functional status. Examples of these include skin grafting, discharged walking without assistance and discharge as well as mobilisation among others as mentioned in Table 2.

We noted that amputation was the treatment option in specific circumstances that were either local related to the ulcer and/or systemic related to the patient health profile. Examples of the ulcer-related circumstances included accidental recognition of the ulcer occurrence, self-treating the ulcer prior seeking professional advice, experiencing more than one ulcer at the same time, and developing recurrent ulcers among other circumstances. Examples of circumstances related to patient health profile included accidental discovery of diabetes at the time of the ulcer, uncontrolled diabetes, and presence of other comorbidities. Further examination of the included articles showed that the time from ulcer occurring to the reported outcome ranged from 4 days to 7 years. It was noted that this time (from ulcer occurring to the reported outcome) increased in certain instances. Examples of these instances included the patient was ignored or was not aware of the ulcer in the initial stages and so no immediate treatment was sought.[43,45,81] Additional instances included trying self-treatment (homemade remedies) prior seeking professional advice,[56,101] receiving treatment in rural settings,[19,93] and experiencing more than one ulcer at the same time.[25,78,80,107] Presence of other comorbidities and delay in referral to a specialist were other examples of circumstances that increased time to treatment (from ulcer occurring to the reported outcome).

4 | DISCUSSION

This systematic review of case reports has expanded knowledge of the external traumas that contribute to the development of foot ulcers among adults with diabetes and built on the findings of an earlier review.[8] Foot ulcers are mainly initiated in the home environment among people with diabetes compared with those without diabetes.[108] This systematic review has identified that the main risks occur within the home environment including during sleep through to outside activities such as swimming and holiday activities. Ulcers that developed from trauma sustained during sleeping were from animal bites and these animals were pets or rodents, supporting our previous claim that the cultural context and/or the socio-demographic profile determine/s the origins of external trauma contributing to foot ulcers.[8] Indeed, pet bites were all reported from very high Human Development Index countries, whereas rodent bites occurred in low, medium Human Development Index countries or rural or poor urban areas of very high and

high Human Development Index countries. A recently published review of records of a specialised Tanzanian diabetic foot care centre showed that 4% (n = 179) of foot ulcers were caused by rat bites over a period of 17 years (from 1999 to 2016).[109] The Tanzanian study considered rat bites (as an origin of trauma contributing to foot ulcers) a risk in developing countries, both rural and urban areas, whereas our review findings extended this risk to very high and high Human Development Index countries. One explanation for this is poor living conditions among people with diabetes living in rural areas and developing nations. Within the context of living conditions, pet bites occurred when people were asleep with their pets. This was reported on more than one occasion for individuals in two reports. This would suggest a lack of health literacy and/ or impaired judgement in that patients' behaviour remained unchanged after the first episode. A lack of health literacy and/ or impaired judgement were also evident in relation to contact burns where the majority of these burns occurred after barefoot walking on hot surfaces or warming feet against hot water bottles/bags. This evidence supports a previous recommendation that foot care prevention programs need to be contextualised to setting.[8]

External traumas reported in this review can be used as examples of possible traumatic risks within the local milieu. The National diabetes foot care audit for England and Wales recommended working with local providers as well as patients to improve the outcome of ulcers.[110] To illuminate this suggestion, we found that several ulcers were sustained by stepping barefooted on sharp objects (toothpick, rough surface, piece of shell on beach). These sharp objects can be highlighted as examples of risks for people with diabetes and to underline the advice that wearing appropriate footwear at all times as a protective layer is vital.[111] Local research by country and region would most likely highlight additional risks that could lead to more localised examples of external trauma, raise patient awareness, and inform prevention strategies. Local research should move beyond reporting the general mechanism of trauma to outlining the origin and the context of the external trauma.[8] The importance of contextualising the external trauma contribution to foot ulcers can be seen in a retrospective analysis of an Australian burn unit records.[108] Although the Australian retrospective analysis was not entirely focusing on those with diabetes and provided the general mechanism of burn injuries, important attributes of foot burns among people with diabetes were documented. These attributes, in addition to the earlier one namely, origins of external trauma are mainly in the home environment, include increasing the risk of contact burns in winter for those with diabetes (n = 53, 40.3%) because of contacting heaters to warm their cold feet. It would be more helpful if the Australian retrospective analysis contextualised origins of the identified traumas against specific criteria. Considering the details provided in the case reports included in this review, reporting criteria should cover detail on local aspects in terms of the origin of the external trauma, time of the incident, mechanism of the incident/ulcer development, how, who and when the ulcer was discovered, and initial treatment sought. The criteria should also include a general patient profile in terms of demographics, health and social and economic factors. Our systematic review detailed the context in which burns were experienced as documented in the included case reports.

We found that ulcers resulted from self-care practices including applying hot water bottles/wheat bags or soaking in foot spas/hot water to treat foot numbness or coldness. Although patients followed manufacturers' instructions, the temperature of the foot bath or foot spa devices would be too high for safe use in people with peripheral neuropathy. Therefore, prolonged contact with hot water bottles/microwaveable heat packs can result in burns even when temperatures are low. Indeed, there is no clear definition of the temperature nor the duration of time recommended for the application of heat and this might be a challenge for people with diabetes as well as for healthcare professionals. People with diabetes do not have the capacity to feel heat because of peripheral neuropathy and/or poor judgement, thereby people with diabetes/care givers need to be warned of the risk of the application of heat even if the temperature is low.[112,113] However, patient education might not result in behavioural change because the required change is lifelong practices and people may not take the advice seriously and translate knowledge into practice.[114] In support of this, difficulties in integrating proper foot care into daily practices were noticed among two groups of people living in Turkey with type 2 diabetes (having a diagnosis of mental illness versus no diagnosis of mental illness).[115] However, both groups believed good self-care might prevent the progression of the disease and avoid the necessity to take insulin. A meta-synthesis of qualitative evidence has argued that there is a complex interaction between patient judgement, social context, and personality that influence whether a person will adhere to medical advice or not.[116] Therefore, the key to understanding why advice is sometimes ignored lays in identifying how these factors interact to better target patient education.[39] In the Turkish study cited above, although both groups regarded social support from health professionals and family members as the most important contributor to self-care, negative attitudes from healthcare professionals or family members were discouraging and

made self-care more arduous. The qualitative systematic review.[116] documented that patient dissatisfaction with foot care received during hospitalisation resulted in a lack of trust and questioning healthcare professionals' capabilities to provide foot care. Accordingly, Coffey et al [116] argued that a holistic approach will help to avoid complications of diabetes in that such an approach provides integrated management combining both physical and mental health care. Involving the family members/care givers might help to individualise foot care programs. Up to 90% (n = 126) of ulcers, collated in this review, could have been avoided if people with diabetes had applied simple measures, worn appropriate footwear, or followed professional advice about foot care.

Family members/care givers involvement will enable tailoring the patient education material to match the risks of the local context, and they can help the patient to avoid sources of trauma. For example, family members/care givers might help in selecting the required form of heat therapy, duration and temperature. This is because those people (family members/care givers) knew more information about the patient and because they can observe, closely, the patient response to heat therapy. In areas where the risk of rodent bites is high, family members/care givers can help in implementing suggestions to minimise the risk of these bites. These suggestions might include helping the patient to clean the home environment, and so become free of rodent infestation. However, family involvement might not be able to eradicate/avoid all possible risks within the home environment and smart wearable technology might be an additional option that can be used to consolidate preventive efforts targeting external traumas.[23,24] Smart technologies focus on detecting plantar pressure where efforts can be made to target people at risk of foot ulceration. Although smart technologies (smart socks) are a possible future way to alert people with diabetes to environmental traumas, the adoption of smart technologies is in its infancy. There are challenges in making these technologies accessible to all people with diabetes for many reasons including financial factors especially for those in low-income countries. Additionally, our review found that traumas could occur during sleep and smart technology might not be able to alert people during sleep. Therefore, family involvement and other preventive efforts need to be promoted to reduce the risk of trauma occurring.

The included case reports contained suggestions that family members can employ to minimise the risk of animal bites. Examples of these additional suggestions include encouraging the people with diabetes to cover their feet whilst sleeping by wearing lose fitting socks at night. Sleeping under mosquito netting is another suggestion that family members/care givers might help the those with diabetes to do to avoid rodent bites. This is in addition to convincing the people with diabetes not to sleep with a pet, reducing the chance of pet bites. Additional examples of incidents/situations to which family members/care givers can alert those with diabetes include undiluted Dettol soaking a slipper while cleaning the floor, urine burn due to incontinence, car keys falling unnoticed into a shoe, hair dryer used to dry wet cast and a small screw embedded in a slipper. Because of the companion with the patient, family members/care givers can also remind the patient to consider their level of activity during unusual events, for example holidays. As cited in our previous review an extra pressure could be made on the foot during the unusual activities resulting from prolonged walking/standing to take the maximum benefit of the holiday.[8] Additionally, people would be very busy, and so they might ignore their usual foot care and/or because of peripheral neuropathy they do not feel pressure on their feet. It would be a good idea encouraging those with diabetes to take regular rests and check their feet during their holidays. The included case reports contained examples of how tailored foot care prevention programs reduced the incident of foot ulcers during holidays.[26] In a review, family members/care givers can alert people with diabetes to avoid possible origins of external trauma in their local context.

4.1 | Limitations

Evidence generated by this systematic review was synthesised from case reports which is a form of anecdotal evidence where clinicians report unusual experiences. Therefore, the generated evidence might not be conclusive in relation to the origins of external traumas contributing to foot ulcers and their outcomes. Additionally, unusual experiences, reported in the included articles, might be the treatment protocol and/or the ulcer outcome but not the origin of external trauma. Indeed, the generated evidence was limited by the depth and the breadth of the details reported on the origin of the external trauma contributing to the development of foot ulcers and their outcomes. A further limitation to consider is that the included case reports were published in the English language, and so possible additional origins of external trauma reported in other languages might have been missed. Most case reports came from very high Human Development Index countries, thereby the generated evidence might not be applicable across all countries.

5 | CONCLUSION

Findings of this systematic review confirm the literature that the origin of external trauma contributing to the development of foot ulcers remain mainly in the home

environment, and these vary by cultural context and/or the socio-demographic profile. Contact with a hot surface and animal bites/stings were the most frequently cited traumas and they were more likely to occur in the home environment. The vast majority of external traumas are avoidable where family members/care givers can help in avoiding possible external trauma. Localised research is required to identify additional origins of external trauma.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data is available on an online platform in the author institution.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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