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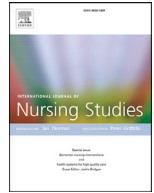
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Foot ulcers associated with external trauma among people with diabetes: An integrative review of the origin of trauma and outcomes

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ABSTRACT

Background: Foot ulcers are common among people with diabetes. These ulcers are caused by a number of factors including trauma. To date, research findings on the origin of external trauma and the outcome of foot ulcers resulting from an external trauma have not been summarised.

Objective: To examine the origin of external trauma that contribute to the development of foot ulcers among people with diabetes and the outcome of such ulcers.

Design: An integrative review.

Settings: Hospital/community.

Participants: Patients with diabetes and foot ulcer.

Method: The Joanna Briggs framework was used to underpin this integrative review. Six different databases (CINAHL +, Medline, SCOPUS, Embase, ProQuest and Web of Science databases) were searched systematically to find research publications reporting traumas that contributed to foot ulcers sustained by people with diabetes. The search was limited to articles published in English. The search revealed 3193 articles that were filtered to 78 articles to be assessed at the full-text level and 45 articles were subsequently included. Quality appraisal was conducted independently by two reviewers, using the Joanna Briggs Institute (JBI) Critical Appraisal tools. Data were extracted into a form developed for the purpose of this review. Narrative synthesis was used to manage the extracted verbatim details on the origin of external trauma contributing to foot ulcers and the outcomes.

Results: The origins of external trauma were summarised into two domains and further specified into 16 categories. The identified traumas were mainly minor and originated within the home environment. The most commonly reported origins of external trauma were puncture wounds, ill-fitting shoes and self-care practices that caused foot ulcers. Twenty-seven studies reported outcomes following the development of an ulcer. Twenty-two studies reported amputation as an outcome and mortality was reported in 10 studies. It was not clear whether these outcomes were directly related to the foot ulcer or related to other diabetes-related complications.

Conclusions: The majority of ulcers occurred in the home environment and were preventable in nature. The assessment of an individual's local context, particularly the home and actions to reduce risk is a priority. The extent of the risks related to external trauma need to be more widely communicated through clinical guidelines and training opportunities for frontline staff.

Tweetable abstract: The main origins of external foot trauma among people with diabetes were puncture wounds, ill-fitting footwear and self-care practices.

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What is already known about the topic?

- People with diabetes are at a higher risk of developing foot ulcers.
- Peripheral neuropathy, foot deformity and trauma are the main factors contributing to the development of foot ulcers.
- Microangiopathy is a major contributing factor to the development of foot ulcers.
- Minor traumas are triggers to foot ulcer development among people with diabetes.
- Delay from time of minor incident to treatment can have potentially serious consequences.

What this paper adds

- The majority of origins of external trauma are located in the home environment.
- Cultural context plays an important role in the type of trauma experienced leading to diabetic foot ulcer.
- Examples of traumas leading to diabetic foot ulcer include bumping the foot against an object, ill-fitting shoes, new shoes, mosquito bites, thorns, barefoot walking, hot liquids, warming numb feet, hot popcorn bag and frostbite.
- Although the traumas are mostly minor and preventable in nature, the resulting ulcer can lead to amputation and/or death.

1. Introduction

Between 19 and 34 percent of people living with diabetes can expect to develop a foot ulcer at some point in their lives (Armstrong et al., 2017). The global prevalence is 6.3% (Zhang et al., 2017). The experience of a diabetic foot ulcer is a strong predictor of further foot ulcers and lower limb amputations (Armstrong et al., 2017; Crawford et al., 2015). The development of an ulcer can occur following trauma and its prevention is vital (Jeffcoate et al., 2018; Schaper et al., 2019). Peripheral neuropathy and foot deformity are the main factors related to foot ulceration (Boulton, 2014; Schaper et al., 2019). Microangiopathy is a contributing factor to diabetic foot ulcers (Nur Rosyid, 2017). Peripheral neuropathy, prevalent in around 50% of people diagnosed with diabetes, masks protective pain sensation and deformities create high plantar pressure areas (Markakis et al., 2016). High pressure can lead to breaks in the foot skin and the development of an ulcer where the pressure exceeds the mechanical resistance of the loaded foot skin. In other words, foot ulcers can develop due to internal factors without an external trauma causing a break in the skin. However, external traumas are reported as common factors contributing to diabetic foot ulceration. Indeed, minor, external traumas with the potential to break the skin or injure the foot are multiple and among those with diabetes can lead to the development of ulcers, some of which will lead to amputation (Ahmad, 2016; Örneholm et al., 2015). One example of a minor trauma is poorly fitting shoes in which the soft tissues of the foot are under pressure for an extended period of time (Boulton, 2014). The severity of outcome following a foot ulcer for people living with diabetes is in part related to the delayed healing process (Bus et al., 2016; Thandavarayan et al., 2015) but also potentially related to a delay in discovering the wound due to peripheral neuropathy and delay in seeking medical advice as a result (Smith-Strom et al., 2017). Increasing awareness of potential traumas among patients, their family and health professionals are important to formulate an approach to prevent and reduce foot ulcers. No review currently exists of the external origins of trauma contributing to the development of foot ulcers among people living with diabetes and the outcome of such ulcers. Identifying the range of origins of external trauma would enable inclusion in clinical guidelines and aid in risk assessment. The International

Working Group on the Diabetic Foot defined ulcers as a skin full thickness lesion where the ulcer is superficial if structures below the dermis layer are not ulcerated (van Netten et al., 2020). The group considered the ulcer deep if structures below the dermis (muscles, bones or tendons) are involved. This review aimed to determine the origins of external trauma reported as leading to the development of foot ulcers among people living with diabetes. The review also aimed to examine the outcomes of foot ulcers sustained as a result of the trauma.

2. Methods

2.1. Design

The design was an integrative review of research publications reporting external traumas that contributed to the development of a foot ulcer in people living with diabetes and the outcome of the ulcer. The Joanna Briggs framework was used to underpin this review.

2.2. Search strategy

The search strategy was developed using a logic grid and PICO framework; P (Population), people with diabetes; I (Interest), external trauma, Co (Context) foot ulcers; and S (Study type) mixed methods/qualitative/quantitative [Supplementary material 1] (The Joanna Briggs Institute 2014). We searched CINAHL +, Medline, SCOPUS, Embase, ProQuest and Web of Science databases, from inception of the database to 2019. We searched from May to August 2016, and again mid-2019.

As recommended by the JBI (The Joanna Briggs Institute, 2014), a preliminary search was conducted in CINAHL PLUS using a range of MeSH terms joined with keywords, using Boolean operators [AND, OR] (Supplementary Material 1). The MeSH terms included diabetic foot, diabetes and injury; and truncation terms diabet*, and injur*. The keywords for the initial search were “burn”, “accident”, “puncture wound”, “animal bite”, “splinter”, “scalds”, “toe injuries”, “pedal puncture wounds” and “shoes”. Then, the CINAHL PLUS and remaining databases were searched using the keywords including additional ones emerged after the initial scanning of the identified articles. These keywords were “home”, “thermal injuries”, “trauma”, “foot injury”, “blister”, “puncture wounds”, “minor trauma”, “wounds”, “rat/rodent bites”, “walking” “The Haj” (Muslim Pilgrimage), “pilgrimage”, “domestic”, “indoor accidents”, “household appliances” and “hot appliances”. The searches were limited to full-text, primary research, peer-reviewed, academic journals in the English language. The searches included ‘Apply related words’, ‘Search within the full-text of the articles’ and ‘Apply equivalent subjects. Additional articles were searched manually from the reference lists of articles identified for inclusion. These efforts resulted in 3193 identified records after excluding duplicates (Fig. 1).

2.3. Inclusion and exclusion criteria

In this review, articles were considered eligible for inclusion if they contained (in the results or the discussion section) details of an external trauma that contributed to the development of an ulcer. Publications were excluded at the title and/or abstract level if they were not primary research studies (reviews, editorials, opinion, case reports), or where the focus of the publication was on prevention, a treatment trial, or an epidemiological report. Articles were excluded if ulcers were solely attributed to diabetic complications with no involvement of an external trauma. Examples of these complications include neuropathy, peripheral vascular disease, Charcot foot and its sequelae. Articles were excluded at

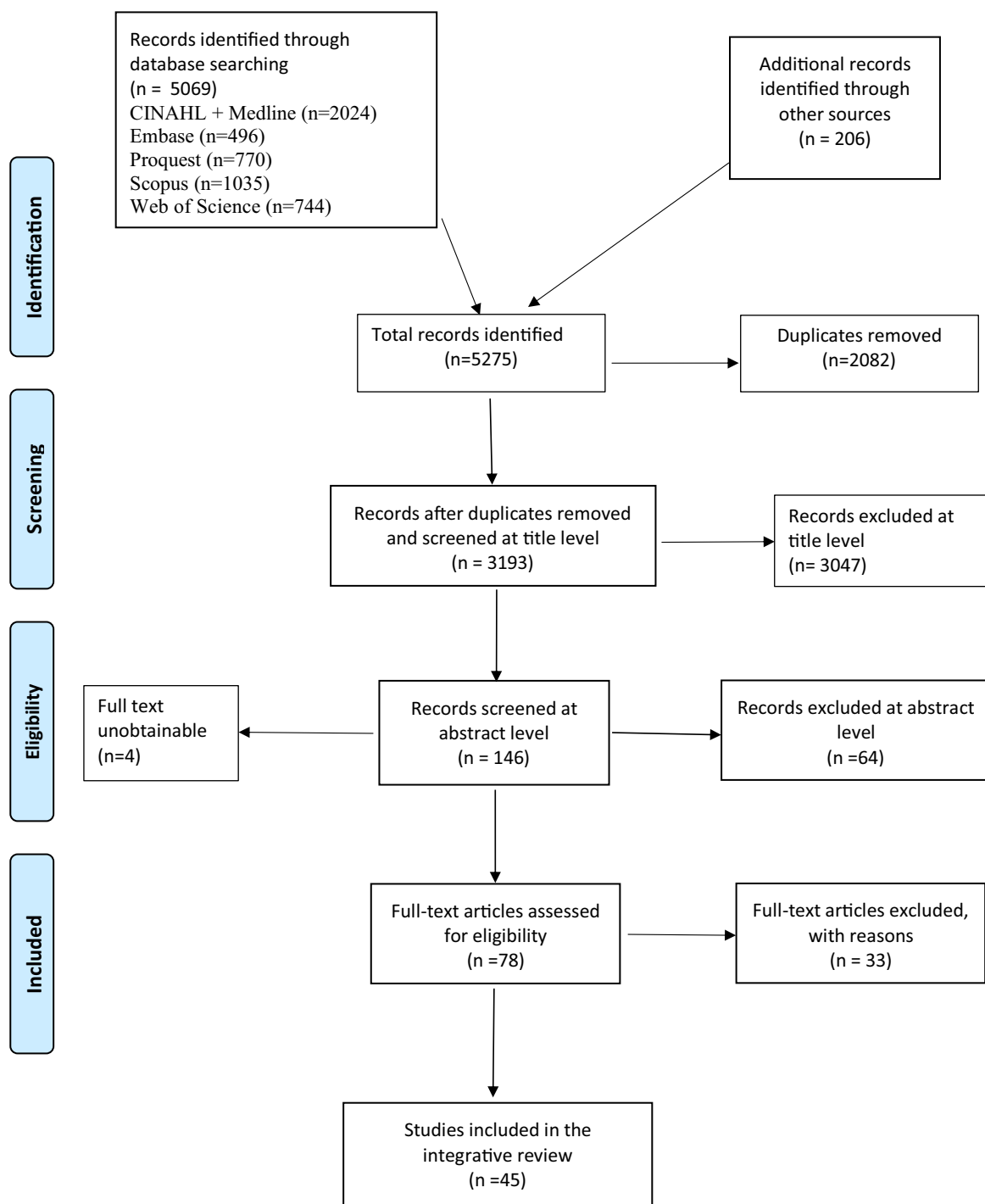


Fig. 1. PRISMA flow diagram adopted from Moher et al., 2009.

the full-text level if detail was missing (from the results or the discussion section) on how the external trauma that led to ulcer development occurred. Within the context of missed detail, articles were excluded if detail on how the trauma occurred was not specified (Supplementary material 2). Similarly, if the provided detail (in the included articles) were insufficient to denote the exact trauma that contributed to the development of an ulcer, data extraction was limited (in the same article) to incidents with enough detail to identify the origin of the trauma. Articles were also excluded if data were presented in another publication included in the review (Supplementary material 2). Extensive efforts have

failed to obtain four articles that merited further consideration at the abstract level (Supplementary material 2). Fig. 1 shows the outcome at each stage that led to 78 articles remaining eligible for full text assessment. The full text assessment deemed 45 articles eligible for inclusion. Fig. 1 sets out the search strategy.

2.4. Quality appraisal

The 45 articles that met the inclusion criteria were quality appraised. Each article was appraised independently, by two reviewers. The second author acted as the second reviewer for

articles reviewed by the other two authors. Any disagreements were resolved through group discussions. For articles published by one of the authors, the two authors without a conflict of interest appraised those individual articles. For the purpose of quality appraisal, JBI Critical Appraisal tools were used to appraise the articles as appropriate to the study design (The Joanna Briggs Institute, 2014). These tools were checklists of questions with three options for each question (YES, NO, Unclear). The JBI Critical Appraisal Checklist for Descriptive/Case Series studies was used to examine 36 articles. Seven articles were appraised using the JBI Critical Appraisal Checklist for Comparable Cohort/Case Control studies. Two articles were appraised using the JBI Critical Appraisal Checklist for Interpretive and Critical Research. The JBI checklists used in this review are available in an online appendix (Appendix 1).

In order to make an estimate of the quality of the paper, responses to critical appraisal questions were scored where a score of two was awarded to the response "Yes", one to the response "Unclear" and a score of zero was awarded to the response "No". The scores were totalled, and the article was classified as either "very good quality" (≥ 15), "good quality" (10–14) or "poor quality" (≤ 9). The majority ($n = 32$) of quantitative studies were assessed as good quality. Nine papers were assessed as very good and four as poor quality because the papers lacked detail on study procedures (Online Appendix 2). The appraisal results were reported to provide detail on the overall quality of the included studies.

2.5. Data extraction

A form was developed to extract "Verbatim" narrative information on origins of external trauma contributing to foot ulcer development and the outcome. Data extraction also included study characteristics in terms of the study design, setting, population and participant demographics. Narrative synthesis (an approach for handling evidence from different types of research) was used to manage the extracted verbatim details concerning origins of external trauma contributing to foot ulcers (The Joanna Briggs Institute 2014). Similar types of external trauma were categorised according to their nature, and then similar categories were aggregated according to the type of trauma.

3. Results

3.1. Study characteristics

The quantitative study designs were case control/comparable cohort ($n = 7$), case series ($n = 21$), cohort ($n = 11$) and descriptive ($n = 4$). Studies were prospective ($n = 18$), cross-sectional ($n = 16$), or retrospective ($n = 9$). Data were generated by accessing clinical records ($n = 17$), mixed methods [interview, and/or medical examination, medical records and medical tests] ($n = 20$) and by interview/survey/questionnaire ($n = 6$). One of the two qualitative studies used a hermeneutic phenomenological approach (Abu-Qamar and Wilson, 2012) and one a descriptive qualitative approach (Feinglass et al., 2012) [Online Appendix 3].

3.2. Settings and populations

The majority of studies ($n = 29$, 64.4%) were conducted in the hospital setting. Ten studies (22.2%) were conducted in community clinics and six (13.3%) were conducted in both hospital and community settings (Online Appendix 3). More than half ($n = 23$) of the studies were conducted in very high Human Development Index Countries, seven in high Human Development Index Countries, two in medium Human Development Index Countries and 10 studies in low Human Development Index Countries (United Nations Development Programme, 2016) [Online Appendix 3]. One

hospital-based study was a cross cultural comparison between a very high, medium and low Human Development Index Countries [Germany, India and Tanzania] (Morbach et al., 2004). One study followed Muslim residents of France travelling to Saudi Arabia on a pilgrimage, both very high Human Development Index Countries (Sridhar et al., 2015). One study did not specify the country in which the study was conducted, although it was in a community clinical setting (Lavery et al., 2006). It was noted that 37.9% ($n = 11$ [24.4% of total n]) of hospital-based studies and 80% ($n = 8$ [17.7% of total n]) of the community clinical settings were very high Human Development Index Countries (Online Appendix 3). Half ($n = 3$ [6.6% of total n]) of the studies conducted in both hospital and community settings were in low Human Development Index Countries.

Sample size ranged from seven to 9710 and the mean sample age range was 44.3 (± 19.0) to 70.5 (± 11.0) years. Time since diagnosis of diabetes ranged from 5.1 (± 4.8) years to 17 (± 12) years (Online Appendix 3).

3.3. Reported traumas

Data comprised of 204 reports of 117 different external traumas that were named as triggers of foot ulcers, and these traumas were mainly sustained in/around the home environment whilst undertaking everyday activities (Table 1). Categorising traumas by nature resulted in the creation of a range of categories that were grouped into two domains, mechanical trauma ($n = 156$, 76.47%), and burns ($n = 48$, 23.53%) (Table 1). Mechanical trauma contained 10 categories including blunt force trauma, foot care actions/practices, footwear related injuries, penetrating/puncture wounds and walking (Table 1). The domain of burns contained six categories: contact burns, flame burns, radiant burns, scalds, burns resulting from foot care practices/action and other burns (Table 1).

Detailed examination of the categories identified found that puncture/penetrating traumas (such as metal nails, glass fragments and splinters) were the most frequent mechanical trauma, of which 11 (21.6%, [5.4% of total traumas]) were due to animal bites or stepping on bone fragments. The second most frequently reported trauma was footwear, which included ill-fitting, incorrectly sized, narrow or tight-fitting shoes and new shoes. The analysis showed that ulcers were triggered by foot care practices or actions ($n = 37$, [72.5% of puncture traumas, 18.1% of total traumas]), examples of these actions included nail trimming, pulling off hard skin, and breaking skin whilst washing feet. Additional examples included burns due to an attempt to warm 'numb' feet, contact with hot water bottles, and immersing feet in hot water. Other forms of external trauma included blunt force trauma (for example stubbing the foot into an object), scalds and spills, pressure ulcers from immobility, and walking. The least frequently reported traumas were flame burns and frostbite (Fig. 2).

3.4. Causes of ulcer deterioration

Nine studies identified factors contributing to ulcer deterioration. These factors included delay seeking medical advice and type of trauma (puncture wound). In a retrospective study, Armstrong et al. (1997) reported that the risk of amputation was increased 46 fold when a puncture wound in a person with diabetes became infected compared to those without diabetes. Armstrong et al. (1997) added that, consequent to the ulcer, people with diabetes were five times more likely to require multiple operations. Conclusively, amputation following ulcer increased when participants did not feel the puncture at the time it occurred (Armstrong et al., 1997). Similarly, it was found that complications were more frequent when ulcers were described as being left untreated or where treatment was delayed

Table 1

Traumas contributed to foot ulcer.

Type of Trauma	Nature of trauma	Reported trauma/Precipitating event
Mechanical trauma	Blunt force trauma	Bumped toe on against furniture or into wall (Payne et al., 1998; Smith et al., 2003) Bumped toe while vacuuming barefoot (Smith et al., 2003) Bumped into cart (Smith et al., 2003) Closing car door on the foot (Payne et al., 1998) Cut to the heel after foot ran into the bed (Smith et al., 2003) Dropping object on foot (Apelqvist et al., 1990; Macfarlane and Jeffcoate, 1997) Knock on a hard object/knocks (Jayasinghe et al., 2007; Macfarlane and Jeffcoate, 1997) Someone trod on foot (Macfarlane and Jeffcoate, 1997) Caregiver trod on foot (Smith et al., 2003) Stubbing the foot on an object (Apelqvist et al., 1990) Treading on something (Macfarlane and Jeffcoate, 1997) Trip or fall over (Anumah et al., 2017; Macfarlane and Jeffcoate, 1997; Tzeng et al., 2013) Walking on/Colliding with jutting stones or gravel (East et al., 2015; Ekpebegh et al., 2009)
	Foot care actions/practices	Bursting a blister [self-home surgery] (Ekpebegh et al., 2009) Cut border of toenail with scissors (Smith et al., 2003) Failure to provide adequate orthotics (Macfarlane and Jeffcoate, 1997) Fragile skin broke during normal washing (Macfarlane and Jeffcoate, 1997) Inadequate attention to orthoses following amputation (Macfarlane and Jeffcoate, 1997) Manual rubbing between toes (Isakov et al., 1992b; Pemayun and Naibaho, 2017) Nail trimming (Altindas et al., 2011; Apelqvist et al., 1990; Isakov et al., 1992b; Walrond and Ramesh, 1998) Poor cleansing and wiping of hallux oedema (Pemayun and Naibaho, 2017) Post-cutting nails (Gulam-Abbas et al., 2002) Provision of foot wear which caused secondary ulceration (Macfarlane and Jeffcoate, 1997) Provision of plaster cast causing secondary ulceration (Isakov et al., 1992b; Macfarlane and Jeffcoate, 1997) Pulled off hard skin (Macfarlane and Jeffcoate, 1997) Removal of callous (Isakov et al., 1992a, 1992b; Pemayun and Naibaho, 2017) Insufficient callous treatment (Altindas et al., 2011) Soaking foot with antiseptic solution and table salt macerating callous (Ekpebegh et al., 2009) Skin broken by adjacent toenail (Macfarlane and Jeffcoate, 1997) Toenail torn off [by sock or bedclothes] (Macfarlane and Jeffcoate, 1997) Tight wound dressing (Ahmed et al., 2010)
	Footwear related injuries	Ill-considered exercise (Macfarlane and Jeffcoate, 1997) Ill-fitting or incorrectly sized shoes/footwear (Altindas et al., 2011; Anumah et al., 2017; Apelqvist et al., 1990; Bakri et al., 2012; Edo et al., 2013; Eregie and Edo, 2008; Lavery et al., 2008; Mayfield et al., 1996; Ngwogu et al., 2013; Nixon et al., 2006; Örneholm et al., 2015; Pemayun and Naibaho, 2017; Shahi et al., 2012; Unachukwu et al., 2007) Lesion attributed to footwear (Smith et al., 2003) Narrow shoes or tight fitting shoes (Edmonds et al., 1986; Ekpebegh et al., 2009; Ogbera et al., 2008) Non-specific rubbing by shoes (Macfarlane and Jeffcoate, 1997) Pressure from footwear (Abbott et al., 2002) Shoe related repetitive pressure (Payne et al., 1998; Pecoraro et al., 1990) Shoe sores (Oe et al., 2015)
	Footwear -New Shoes	Steeled-toed shoes rubbing against toes (Feinglass et al., 2012) Blister from wearing new shoes (Ahmed et al., 2010) New shoes (Isakov et al., 1992a; Macfarlane and Jeffcoate, 1997; Mayfield et al., 1996) New shoes provided by an orthotist (Macfarlane and Jeffcoate, 1997)
	Footwear - socks	Prolonged wearing of tight new shoes (Isakov et al., 1992a) Ill-fitting socks (Apelqvist et al., 1990) Socks too thick (Macfarlane and Jeffcoate, 1997)
	Pressure Ulcers	Bed sores to heel/Decubitus ulcer (Edmonds et al., 1986; Ekpebegh et al., 2009; Mayfield et al., 1996; Örneholm et al., 2015; Pecoraro et al., 1990; Smith et al., 2003; Tzeng et al., 2013) Immobilisation due to other illnesses in hospital or nursing home (Macfarlane and Jeffcoate, 1997) Immobilisation due to other illnesses at home (Macfarlane and Jeffcoate, 1997; Smith et al., 2003) Pressure due to immobilisation of foot in bed or chair (Apelqvist et al., 1990)
	Penetrating/puncture wounds caused by animals	Antelope bite (Anumah et al., 2017) Dog bone (Armstrong et al., 1997) Fish bone (Armstrong et al., 1997) Mosquito bites (Morbach et al., 2004) Rat bites (Abbas et al., 2005; Anumah et al., 2017; Ekpebegh et al., 2009; Eregie and Edo, 2008; Morbach et al., 2004; Ngwogu et al., 2013; Pemayun and Naibaho, 2017)
	Penetrating/puncture wounds	Barbed wire (East et al., 2011) Coat hanger (Armstrong et al., 1997) Foreign body in shoes (Macfarlane and Jeffcoate, 1997) Glass/glass fragment (Armstrong et al., 1997; East et al., 2015, 2011) Metal fragment (East et al., 2015, 2011) Metallic axe fragment (Armstrong et al., 1997) Metallic fragments in carpet (Armstrong et al., 1997) Nail – metal (Anumah et al., 2017; Armstrong et al., 1997; East et al., 2015, 2011; Ekpebegh et al., 2009; Pemayun and Naibaho, 2017; Shahi et al., 2012; Unachukwu et al., 2007) Nail piercing through shoes (Ekpebegh et al., 2009) Nail through rubber soled shoes (Rubin et al., 2010)

(Continued on next page)

Table 1 (Continued).

Type of Trauma	Nature of trauma	Reported trauma/Precipitating event
		Needle/pin (Armstrong et al., 1997; East et al., 2011; Jayasinghe et al., 2007)
		Splinter/wood fragment/wood sliver (Armstrong et al., 1997; East et al., 2011; Feinglass et al., 2012)
		Stepping on sharp object (Apelqvist et al., 1990; Isakov et al., 1992a)
		Tack (Armstrong et al., 1997; Payne et al., 1998)
		Tip of machete (East et al., 2011)
		Thorn (Armstrong et al., 1997; East et al., 2011; Jayasinghe et al., 2007)
		Thumbtack (East et al., 2011)
		Treading or stepping on Rock/Stone/Gravel (Armstrong et al., 1997; East et al., 2015, 2011; Edmonds et al., 1986)
		Wire (Armstrong et al., 1997)
	Toenail issues	Ingrown toenails (East et al., 2015; Macfarlane and Jeffcoate, 1997; Payne et al., 1998; Pemayun and Naibaho, 2017; Rivera, 1998)
	Walking	Blisters from walking on hot surface after slippers or open-toed shoes had been removed or slipped off (Ahmed et al., 2010)
		Blisters from walking long distances during the Haj Pilgrimage (Alfelali et al., 2014; Morbach et al., 2004; Sridhar et al., 2015)
		Puncture from barefoot walking (Edo et al., 2013; Eregie and Edo, 2008)
		Foot lesions from walking barefoot on the beach (Morbach et al., 2004)
		Foot lesions from walking barefoot in the sea (Morbach et al., 2004)
		Foot lesions from walking barefoot on a wooden floor (Morbach et al., 2004)
		Unaccustomed exercise during foreign holidays (Morbach et al., 2004)
Burns	Contact burns	Contact burns
		Contact with cooker (Macfarlane and Jeffcoate, 1997)
		Contact with heater (Abu-Qamar and Wilson, 2012; Nerone et al., 2014)
		Direct contact with hot pot (Abu-Qamar and Wilson, 2012)
		Engine block from mower (Nerone et al., 2014)
		Exhaust pipe on a motor cycle (Ekpebegeh et al., 2009; Nerone et al., 2014)
		Hot popcorn bag (Nerone et al., 2014)
		Resting foot on hot ash (Abu-Qamar and Wilson, 2012)
		Resting foot on the engine compartment of a commercial combi bus (Ekpebegeh et al., 2009)
		Walking barefoot on a hot sandy beach (Katcher and Shapiro, 1987)
		Walking barefoot on a blacktop driveway/hot asphalt (Katcher and Shapiro, 1987; Nerone et al., 2014)
		Walking on a hot or very cold surface (Barsun et al., 2013)
	Flame burns	Flame burns (Katcher and Shapiro, 1987; Macfarlane and Jeffcoate, 1997)
	Foot care practices/action resulting in burns	Attempting to warm numb feet (Ogbera et al., 2008)
		Heating pad (Katcher and Shapiro, 1987; Nerone et al., 2014)
		Hot compress to numb feet (Edo et al., 2013)
		Hot moist compress (Katcher and Shapiro, 1987)
		Hot bottle (Isakov et al., 1992a)
		Hot water bottle (Macfarlane and Jeffcoate, 1997)
		Hot tap water on feet during bathing or foot care (Abu-Qamar and Wilson, 2012; Katcher and Shapiro, 1987)
		Immersing foot/feet in hot water (Nerone et al., 2014)
		Putting feet on a hot surface to 'test if they were working' (Ekpebegeh et al., 2009)
		Soaking feet in hot or "warm" water (Barsun et al., 2013; East et al., 2015)
		Soaking feet in water (Rivera, 1998)
	Radiant Burns	Infrared radiation burn (Tzeng et al., 2013)
		Sunburn to exposed feet (East et al., 2015; Jones et al., 2015)
		Warming feet near or too close to a heater (Abu-Qamar and Wilson, 2012; Barsun et al., 2013)
		Warming feet near a camp fire (Katcher and Shapiro, 1987)
	Scalds	Grease (Nerone et al., 2014)
		Hot liquids (Isakov et al., 1992b; Jones et al., 2015)
		Hot water (East et al., 2015)
		Hot water splashing on feet while cooking (Abu-Qamar and Wilson, 2012)
		Scald burns from coffee (Katcher and Shapiro, 1987)
		Spilling hot fluid on foot/feet (Apelqvist et al., 1990; Barsun et al., 2013; Isakov et al., 1992b)
		Warming 'numb' feet (Eregie and Edo, 2008)
	Other burns	Frostbite (Barsun et al., 2013; Pecoraro et al., 1990)

(Abbas et al., 2005; Anumah et al., 2017; Armstrong et al., 1997; Edo et al., 2013; Nerone et al., 2014). Indeed, Edo et al. (2013) reported that 12 (19.6%) participants discharged themselves from hospital against medical advice, and Table 2 does not include these participants. Edo et al. (2013) added that delayed presentation for treatment was associated with a higher grade ulcer and increased the likelihood of amputation. They found that the higher the Wagner grade (a classification system to grade the severity of an ulcer) the more likely an outcome of amputation was observed. Specifically, 20 of the 27 patients with Grade IV and the one patient with a Grade V ulcer underwent amputation, compared to nine of 28 people with a lower Wagner grade undergoing amputation.

Barsun et al. (2013) also reported that the length of time from incident to treatment was statistically longer in the insensate (those with peripheral neuropathy) group (9.5 ± 28.3 days) compared to the sensate (those without peripheral neuropathy) group (2.9 ± 2.1 days). Two patients in the sensate group underwent amputations (6.5%) compared with nine (24.3%) in the insensate group.

In two studies, mortality was related to complications arising from the original trauma, in spite of the medical treatment received (Abbas et al., 2005; Pemayun and Naibaho, 2017). Pemayun and Naibaho (2017) found the main cause of death was sepsis arising from the ulcers (59%). Ekpebegeh et al. (2009) commented that mortality could be partially explained by patients

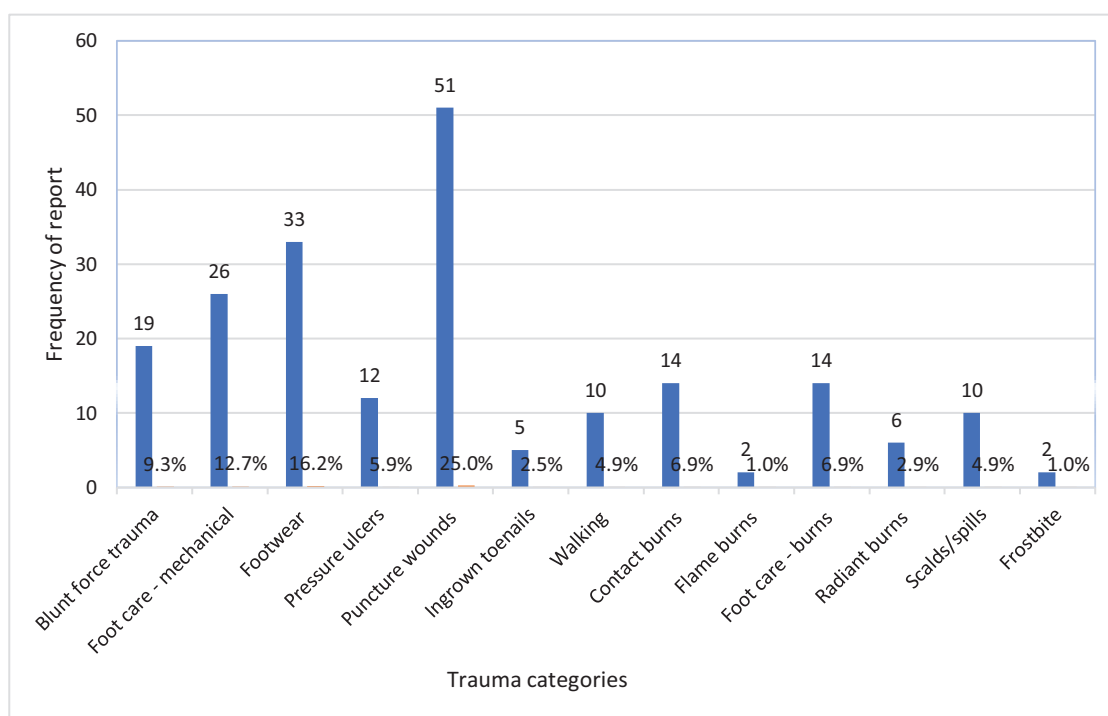


Fig. 2. Trauma categories and frequency of report.

refusing amputation, particularly in those with a higher Wagner grade. In the remaining studies included in this review, it was unclear whether the reported mortalities and/or complications were a result of the foot ulcer or related to pre-existing co-morbidities.

3.5. Outcomes

Twenty-seven (60%) studies reported the outcome of foot ulcers (Table 2). Studies reported the outcomes by the number of ulcer episodes not by the number of participants (East et al., 2011). East et al. (2011) detailed that 35 (45.4%) episodes healed without medical intervention and 21 (27.3%) without surgical treatment. Amputation as an outcome was reported in 22 studies (48.9% of total n). It should be noted that certain studies were limited to those having amputation that was linked to preceding events retrospectively (Feinglass et al., 2012; Isakov et al., 1992a,b; Mayfield et al., 1996; Pecoraro et al., 1990).

Ten (22.22%) studies reported mortality as an outcome of the ulcer caused by a minor external trauma (Table 2). The highest mortality rate ($n = 83$, 12%) was reported in Orneholm et al.'s study (2015). The lowest rate ($n = 1$, 12.5%) was reported in Tseng et al.'s (2013) study. The total mortality rate was 192 ranging from 3% ($n = 2$, total $n = 68$) to 40.4% ($n = 17$, total $n = 42$). Finally, only one study (Payne et al., 1998) noted mental health or cognitive impairment as co-morbidities. Payne et al. (1998) reported that almost 27% ($n = 13$) of the study sample were diagnosed with a mental illness or other cognitive impairment.

4. Discussion

This integrative review is the first to collate information on the origins of external trauma that contribute to the development of foot ulcers sustained by people living with diabetes. An integrative

review was completed rather than a systematic review in order to include as much evidence as possible on the origins of external trauma and the outcome of ulcers from studies that used a range of methodological approaches. JBI quality appraisal tools have been developed to assess quality across a wide range of methodologies (The Joanna Briggs Institute, 2014) and were considered appropriate to assess the quality of the included studies. The reviewers extracted "verbatim" the origins of reported external trauma. The origins of trauma were summarised into two domains and further specified into 16 different categories. The majority of traumas was experienced in the home environment and was related to everyday activities including housework such as vacuuming, gardening and food preparation. The studies included in the review also contained reports of traumas that resulted from self-care activities or the action of healthcare professionals. Some traumas were related to cultural commitments, for example funerals and family gatherings for religious occasions. It is important that clinical guidelines consider accommodating the cultural context of the country or geographical region that they cover to highlight potential risks within a local context.

Wearing inappropriate footwear was a common origin of trauma identified across all studies, and included reports of ill-fitting shoes, resulting in blisters/ulcers, and inadequate or non-protective footwear associated with punctures. In the literature, it is well acknowledged that trauma can originate from footwear among people living diabetes (Barwick et al., 2018; Premkumar et al., 2017; Schaper et al., 2019). The lack of protective footwear during the Haji (pilgrimage) was reported as a major precipitating factor in sustaining a subsequent ulcer for pilgrims (Alfelali et al., 2014; Sridhar et al., 2015). Similarly, studies cited an association between foot ulcers and exercise undertaken on holiday (Morbach et al., 2004). Changes in routine are associated with trauma during pilgrimage and holidays (Morbach et al., 2001; Pickin et al., 2008; Thompson, 2012). This review provides an update on existing literature in this specific field.

Table 2
Ulcer outcomes.

Author	Outcomes			
	Ulcer Healed N (%)	Amputations		Death N (%)
		Minor N (%) (toes, partial foot)	Major N (%) (Foot, partial limb)	
Abbas et al. (2005)	30 (88.00)	13 (38.00)	4 (12.00)	4 (12.00)
Ahmed et al. (2010)	65 (53.50)	50 (41.00)	7 (5.70)	0.00
Altindas et al. (2011)	124 (20.60)	431(72.0)	45 (8.00)	0.00
Anumah et al. (2017)	75 (72.80)		13 (12.6)	9 (8.70)
Apelqvist et al. (1990)	197 (63.00)	2 (0.06)	77 (24.00)	40 (13.00) ⁱ
Armstrong et al. (1997)	... ^a	27 (35.10)	4 (5.20)	0.00
Barsun et al. (2013)	56 (82.00)	5 (7.30)	7 (10.30)	2 (3.00)
East et al. (2015)	... ^a	34 (27.40)	41(33.10)	0.00
East et al. (2011)	67 (86.90) ^{b,c}	5(6.50)	2 (2.60)	0.00
Edmonds et al. (1986)	204 (86.00) ^{b,d}	18 (12.20) ^d	4 (2.70) ^d	0.00 ^d
	107 (72.00) ^{b,e}	10 (6.70) ^e	16(17.60) ^e	0.00 ^e
Edo et al. (2013)	21 (33.90) ^k	3 (5.40)	16 (26.80)	9 (14.30)
Ekpebegh et al. (2009)			... ^a	17 (40.40)
Feinglass et al. (2012)	... ^{l, f}	1 (4.5%) ^f		21 (95.50) ^f
Isakov et al. (1992a)	... ^l		44 (100) ^l	0.00
Isakov et al. (1992b)	... ^l		56 (100) ^l	0.00
Jones et al. (2015)	17 (94.5%)	0	1 (5.50)	0.00
Mayfield et al. (1996)	... ^l	42 (68.8)	19 (31.20)	0.00
Nerone et al. (2014)	28 (84.8)	4 (12.12)	1 (3.03)	0.00
Rubin et al., (2010)	96 (100) ^g		0	0.00
Örneholm et al. (2015)	558 (79.6)		60 (9.00)	83 (12.00) ⁱ
Payne et al. (1998)	36 (81)		9 (19.00)	0.00
Pecoraro et al. (1990)	... ^l	47 (58.7)	33 (41.30)	0.00
Pemayun and Naibaho (2017)	117 (50.00) ^b	74(32) ^b	24 (10.00) ^b	23 (10.70)
Shahi et al. (2012)	91 (93.81)	13 (13.40)	2 (2.06)	0.00
Smith et al. (2003)	... ^a	5 (1.25)	6 (1.50)	0.00
Tzeng et al. (2013)	7 (87.50)		0	1(12.50) ⁱ
Unachukwu et al. (2007)	49 (81.66)	7 (11. 66)	5 (8.30)	4 (6.70)

^a Not reported.^b Results reported by number of wound episodes. Not participant numbers.^c Healed without medical intervention.^d Neuropathic group.^e Ischemic Group.^f It is unclear how many of these were diabetic.^g 5.21% needed more than one operation or developed osteomyelitis^hIt is unclear how many of these are the result of burns to the foot only.ⁱ It is unclear if death was ulcer related.^k The figure given in the table does not include 12 participant (19.6%) who Discharged against medical advice.^l the study population was all amputees.

A proportion of participants across all studies reported that they were not immediately aware that an ulcer had developed. This in turn resulted in a delay in seeking medical treatment until such time as a relative or health professional noticed the ulcer, sometimes, days or weeks later. Although it is not new information that, following foot trauma, people with diabetes belatedly seek medical care (Armstrong et al., 2017; Goutos et al., 2015), it is timely to again raise the issue that minor, preventable traumas can be associated with serious outcomes. The National diabetes foot care audit for England and Wales confirmed that people who delay seeking medical advice are at greater risk of poor health outcomes (NHS Digital, 2019). Indeed, healing among people with diabetes is significantly diminished because of poor perfusion resulting mainly from microangiopathy plus other factors including oedema, infection and decreased tissue oxygenation (Hinchliffe et al., 2019). Foot care guidelines need to highlight the messages that a failure to recognise the initial minor trauma and a delay in seeking treatment can increase the risk of infection, extend the time to heal and is associated with poor health outcomes (Amin and Doupis, 2016). Although the frequency of amputation was low compared to amputations associated with chronic neuropathic ulcers, the event of an amputation secondary to a minor and preventable trauma is of concern. In studies included in this review, delayed treatment-seeking was associated with the development of gangrene, increase in skin grafting procedures and higher rates of amputation and death. In an analysis of incidents triggering

diabetes-related amputations, delay in help-seeking behaviour was considered the main reason for amputation in 42% ($n = 36$) of participants (Win Tin et al., 2013).

Many people with diabetes do not seek immediate treatment because of the impaired pain sensation secondary to neuropathy. Evidence generated by this review found that additional factors also delayed presentation for the treatment of foot ulcers. Examples of the additional factors include low health literacy, distance to travel for treatment and the cost of healthcare. Issues related to the cost and accessibility of healthcare can encourage the use of home or folk remedies before seeking medical treatment. Geographical variations in the quality of diabetic foot care exist (Jeffcoate et al., 2018) and a possible cause of variation in the quality of care provided is lack of knowledge and training for nurses and medical doctors. Existing guidelines include trauma as a risk factor but normally limit these to footwear and acute injury without detailing the potential origins of external injury (Bus et al., 2019; Diabetic Foot, 2016). This integrative review extends knowledge and has generated a list of possible origins of external trauma and their context.

Finally, only one study discussed the rate of mental illness among participants (Payne et al., 1998). It is known that people living with co-morbid mental health issues and diabetes face disparities in healthcare compared to people without mental illness (Mangurian et al., 2020). The effects of the mental illness itself, medication side effects (such as weight gain), lifestyle, and

problems with day-to-day living can all impose substantial barriers to diabetes self-management (Thomas, 2015). It is unknown how many people living with mental illness and diabetes have adverse foot-related outcomes due to the combination of these factors. We suggest that these two areas warrant further research attention to estimate the incidence of foot ulcer among people with diabetes and mental health problems and the outcomes of such ulcers.

5. Limitations

This integrative review has several limitations to be considered. One researcher (The second author) conducted the search and screened the articles at the title and abstract levels. However, the search strategy was developed by the review team and weekly meetings were held to discuss the process and consider publications when the decision to include a paper for full text review was not clear cut. Although this integrative review included a relatively large number of research publications, several papers were excluded due to the lack of detail provided on the origin of the trauma. A key observation was the lack of detail around how trauma contributed to ulcer development especially when this was not the primary focus of the publication. Epidemiological studies for example often referred to trauma as a collective term but did not specify the origins of the trauma. The traumas identified were often reported as an aside within the study and were subsequently excluded because they did not provide the detail we sought in this review. In this review, each external origin of trauma reported in the included studies was assigned a frequency of one per paper (Table 1). This is because some authors did not include frequency associated with each trauma in their paper. For the purpose of this review, the report of trauma was taken verbatim and we did not conflate origins that were not directly made by the authors, for example “bumping the foot against an object” and “bare-foot walking” were considered as two individual traumas even though bumping a foot against an object might be associated with barefoot walking. Four studies were included in this review that were rated as poor quality following the methodological appraisal, however this was mostly because not enough detail was provided on the methods rather than an absence of information or because the authors had concerns about the quality of the studies. Further, this review was limited to papers published in English and the included studies were mainly from very high Human Development Index Countries and high Human Development Index Countries, thereby the generated evidence might not be applicable to all countries. An additional point, information on reported traumas were most likely obtained verbally from the patients and/or their support person. It is unclear to what extent researchers verified the accuracy and/or completeness of the provided information. Standardised reporting criteria on the origin of external trauma that contribute to foot ulcers would improve guidelines. Finally, extensive efforts failed to obtain a full copy of some articles ($n = 4$) that were considered relevant to the review on reading the study abstract.

6. Conclusion

This integrative review highlighted a range of traumas that led to the development of foot ulcers in people living with diabetes. The origins of external trauma were varied but commonly the trauma occurred within the home and was preventable in nature. Considering these findings, it is reasonable to suggest that clinical guidelines need to include information to raise awareness of the potential origin of external trauma and outcomes. Clinical guidelines also need to consider cultural variations in relation to the environment and cultural practices.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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