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Occupational Injury Patterns and Safety Risks in Humanitarian Demining: A Systematic Review

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Abstract

The morbidity and mortality associated with landmines and explosive remnants of war remain a significant problem worldwide. Deminers exposed to these hazards repeatedly in their line of duty have not had their injury patterns adequately synthesized in over two decades and mine contamination continues to expand in modern conflicts.

A systematic review was conducted in accordance with PRISMA 2020 guidelines. Inclusion criteria were studies that documented injury patterns, injury mechanisms, personal protective equipment (PPE), and outcomes in deminers.

Eight studies published between 1990 and 2025 met the inclusion criteria. Demining activities were associated with high injury and fatality rates across all studies. Most injuries involved handling anti-personnel mines; upper limb trauma (62%) and amputations, which were commonly reported, distinguished deminers from other civilian and military populations exposed to explosive devices. Despite improvements in personal protective equipment, facial and ocular injuries remain prevalent. Deminers had better survival rates than civilians, often due to rapid evacuation and on-site medical support; however, only 20% returned to clearance work post-injury. Contributing risk factors included procedural lapses, inadequate training, and poor supervision.

Although advancements have improved safety, current evidence remains limited and outdated. Systematic injury reporting and updated analysis of injury data are urgently needed.

Key Points

What is already known on this topic—Humanitarian demining is acknowledged as a hazardous occupation; however, most of the existing evidence about landmine injury distribution is based on civilian or military populations. The limited literature available specifically for this high-risk occupational group has been largely published more than two decades ago and prior to the modern methods of landmine clearance, personal protective equipment, and medical care. Additionally, landmines are being used increasingly across the world due to renewed deployment in several conflicts.

What this study adds—This structured review examines all the existing published evidence about injuries sustained by adult deminers, proving the existence of characteristic occupational injury distribution patterns, especially in upper limbs, eyes, and amputations, which differ from those of other mine-affected populations. It points out the existing gaps in injury reporting, outcomes, and documentation of protective measures.

How this study might affect research, practice, or policy—This review consolidates the existing evidence base and provides an occupational health framework for risk assessment, injury prevention, and medical planning for demining operations, while emphasizing the need for systematic and contemporary data collection. We have already collaborated with the HALO Trust, one of the largest demining charities in the world, with these results to help inform their practices.

Introduction

Landmines remain a persistent hazard in conflict-affected regions. They continue to injure, kill, maim, and cause long-term disruption to civilian life many years beyond the end of an armed conflict. Since systematic reporting began in 1999, over 159,000 people worldwide have been killed or injured by landmines and Explosive Remnants of War (ERW).[1] An estimated 110 million landmines remain buried across almost 70 countries and territories, despite sustained

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humanitarian clearance activity.[2] In 2023 alone, at least 5757 people were killed or injured worldwide by landmines and ERW, which is a 22% increase compared to the total for 2022—84% of the casualties were civilians, and 37% were children. This threat can only truly be removed permanently through clearance operations; however, these operations are labor-intensive, expensive, and dangerous for the personnel undertaking them.[1]

More recent conflicts have exacerbated concerns regarding widespread ERW contamination and the likelihood of renewed deployment of mines. The ongoing Russo-Ukrainian War has resulted in the most mine-contaminated territories since the Second World War,[3] with suggestions that up to 30% of Ukraine's land area may now be contaminated.[4] Clearance efforts are ongoing even as the conflict continues.[5] In addition, six European states—including Ukraine and several border states around Russia—have initiated withdrawal from the Ottawa Treaty citing security concerns, raising the prospect of an escalation in the use of mines in the future.[6] These more recent developments serve to reinforce the fact that landmines are not solely a legacy issue stemming from historical conflicts, but an evolving feature of modern warfare, and raise the importance of sustained clearance capacity and improving the understanding of the risks faced by the demining workforce.

Humanitarian deminers continue to provide the bulk of international clearance, normally in partnership with national authorities, NGOs, and international agencies. Their work places them in repeated and direct contact with live explosive devices, ranging from anti-personnel mines designed to maim or kill individuals to anti-vehicle mines carrying larger charges that can inflict multiple casualties. Despite accounting for only approximately 2% of the recorded global mine and ERW casualties since 1999, their occupational exposure carries a distinct risk.[1] Unlike civilians, who may encounter mines by chance, deminers face these threats daily as part of their routine work, and their safety relies heavily on personal protective equipment, specialized training, and strict operational procedures to minimize risk. Along with the increasing deployment of conventional landmines, the growing use of improvised explosive devices, and the emergence of drone-delivered munitions in recent conflicts,[7] the global demining community faces an expanding and evolving threat landscape. The sector's focus should not only be on timely removal but also on the long-term safety, resilience, and well-being of its personnel.

Most existing knowledge of landmine injury patterns is based on studies of military personnel and civilians injured outside of planned clearance operations.[8,9] While these provide valuable insights into injury mechanisms, these findings cannot be generalized to humanitarian demining due to its unique operational exposures, work practices, and protective measures. Moreover, most studies of deminer injuries are now more than two decades old,[10,11] and predate improvements in personal protective equipment, the development of new clearance techniques, and alterations in the nature of the explosive contamination encountered in more recent conflicts.

With growing geopolitical instability and a real possibility of repeated large-scale conflicts, the risk of injury due to mines will continue to rise, with potential consequences lasting for generations. Therefore, there is an urgent requirement to define, assess, and enhance protections for demining personnel. It is equally important to protect this workforce in order to maintain skilled workers in the humanitarian sector and fulfill a larger ethical commitment toward the protection of those who work on the front lines of mine clearance.

Study Objective

To systematically identify and synthesize the existing evidence on injury patterns and clinical outcomes among adult deminers.

Methods

Study Design

This study is a literature review, informed by structured methodology and guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 recommendations.[12] No formal pre-review protocol was registered.

Search Strategy

A comprehensive search strategy was developed to identify literature describing injury patterns resulting from landmine detonations among adult deminers, with attention to variation by mine type and personal protective equipment (PPE) usage.

The following electronic databases were searched:

Web of Science, Scopus, MEDLINE, EMBASE, CINAHL, Cochrane Library, and EBSCO. In addition, other gray literature sources were searched, including:

(1) Journal of Conventional Weapons Destruction (CWD)
(2) International Committee of the Red Cross (ICRC)
(3) United Nations Mine Action Service (UNMAS)
(4) Geneva International Centre for Humanitarian Demining (GICHD)
(5) Mines Advisory Group (MAG)

Search strings were tailored to each database, using combinations of structured indexing terms (e.g., MeSH) and free-text keywords. Boolean operators (AND, OR) were used to combine search terms. A representative search string from MEDLINE is provided below:

((injur* OR wound* OR trauma OR blast OR "blast injury" OR fatal* OR death OR mortalit* OR morbidit* OR ampu* OR casualt*)) AND ((anti-personnel OR "anti personnel" OR anti-tank OR "anti tank" OR "anti-vehicle" OR "anti vehicle" OR AV OR "anti-group" OR IED OR "improvised explosive device" OR "victim-operated" OR "unexploded ordnance" OR UXO)) AND (("humanitarian mine action" OR HMA OR "landmine clearance" OR mineclearance OR "mine clearance" OR demining OR "mine action" OR clearance OR "de-mining" OR deminer* OR "mine risk education"))

Eligibility Criteria

To accommodate the limited and interdisciplinary nature of the topic, broad inclusion criteria were applied. Studies were eligible for inclusion if they:

(1) Reported on injuries or trauma resulting from landmine detonations
(2) Included adult deminers (civilian or military)
(3) Provided data or discussion on mine types and/or PPE use
(4) Were published in English
(5) Included peer-reviewed publications, conference papers, or gray literature (e.g., NGO or governmental reports)

Exclusion criteria:

(1) Articles with a study population comprised solely of military personnel or civilians injured as landmine victims outside of active demining operations

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(2) Technical documents on explosive ordnance disposal (EOD) without reference to injury or human impact
(3) Literature unavailable in full text
(4) Opinion pieces without empirical or operational data

No restriction was placed on geographic region or study design. Literature from 1990 onward was considered to reflect the modern period of formalized HMA activities. Pre-1990 literature was considered unlikely to reflect the operational context, protective equipment, or working practices relevant to contemporary humanitarian demining.

Screening and Study Selection

Figure 1 contains a full breakdown of the literature search.

An initial search retrieved 1532 records from the listed academic databases. Additional studies were identified through:

(1) Citation searching (n = 6)
(2) Gray literature searches (n = 3)
Total additional records: n = 9

After duplicate removal, titles and abstracts were screened for relevance by two reviewers. A total of 22 articles were reviewed in full text, and 8 studies met the final inclusion criteria.

Due to heterogeneity in study design, population definitions, and reporting standards, formal meta-analysis was not possible.

Results

In total, 1541 studies were retrieved from Web of Science, Scopus, PubMed, Cochrane, EBSCO, CINAHL, EMBASE, and gray literature. Following duplicate removal, 1054 studies were screened against the exclusion criteria detailed in the methods. Two reviewers assessed full texts for eligibility of the remaining 22 studies. Across the eight included studies in the final review, there was a combined total of approximately 3418 deminers.

Incidence and Severity of Demining Injuries

Across the reviewed literature (Table 1), mine clearance consistently emerges as an occupation with a high incidence of severe injury. The HALO Trust's 10-year prospective study, which was conducted between 1991 and 2000, documented that there were 92 traumatic injuries among 73 deminers. This equated to a fatal injury rate of 116 per 100,000 workers per year and a major injury rate of 485 per 100 000 workers per year. Of these, 11 (15%) were fatally injured.[10]

The estimated accident frequency from a study in Afghanistan suggested that 1 severely injurious incident occurs for every 32 field deminers annually.[13] Croatian data collected between 1991 and 1995 revealed a high mean Injury Severity Score (ISS)[14] of 19.68 ± 8.57. Their mortality rate was much lower, with 2 fatalities among 53 injured deminers.[15] Radonić et al. were the only authors to

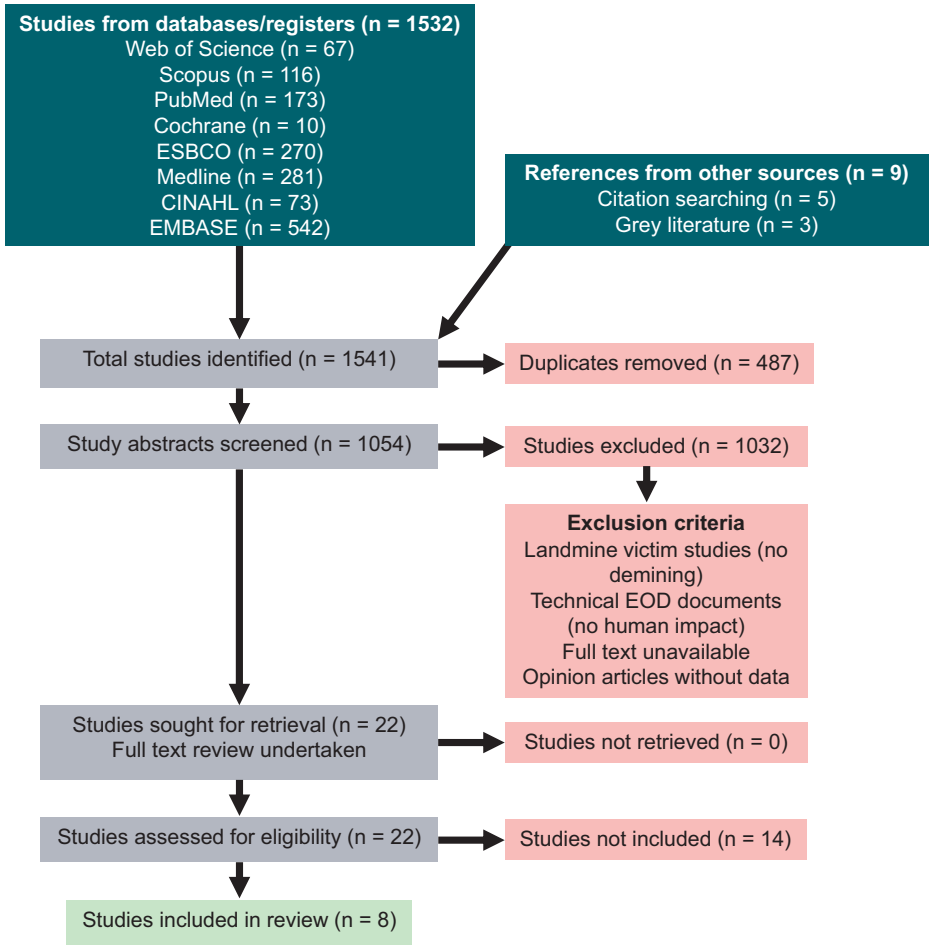


Figure 1. Literature search flow diagram.

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Table 1. Characteristics and reported injury outcomes of included studies

Study	Country	Setting	Study design	Data source	Study period	Population	No. of deminers	No. of incidents	Mechanism/ device	PPE reported	Predominant injury pattern	Amputation	Mortality	Injury severity and metrics	Return to work	Key notes	Limitations
Brown et al., 2001	Abkhazia, Afghanistan, Angola, Cambodia, Chechnya, Mozambique, Nagorno Karabakh	Post-war minefields	Prospective database review	HALO Trust database	1991–2000	Civilian deminers	9541 person-years*	73 patients	Handling AP mine (51%); standing on mine (20%)	Protective visors (mandatory after 1995)	Upper extremity and facial trauma (62%); total extremity trauma (59%); lower extremity trauma (20%).	30% overall	15% (11 fatalities)	Administrative classification: 63% major/22% minor (categorized by the UK National Statistics Office)	20%	Facial injury rate fell after visors	Restricted to a single charity's data
Coupland et al., 1991	Asia and Africa	Two war-theatre hospitals	Retrospective analysis	ICRC clinical records	One calendar year (specific dates not reported)	Military and civilian deminers	41 cases of incidents involving mines being handled (P3)	757 patients	P1: Standing on buried mine; P2: Triggering fragment mine; P3: Handling mine (digging / defusing)†	Footwear noted as factor	Most common patterns across all 757 patients: multiple fragment wounds (48%–49% of cases, P2); traumatic lower extremity amputation (P1); upper extremity and facial trauma (P3)	P1 = 15% lower limb amputation; P3 = 30% upper limb amputation	0.8% (6 patients)	Resource-based severity: Pattern 1 injuries are identified as the "greatest drain" on surgical time and blood resources	Not reported	Defined 3 recognizable injury patterns	Survivors only; long evacuation (6+ hrs)
Radonić et al., 2004	South Croatia	Military/ humanitarian demining	Retrospective study	Clinical Hospital Split	1991–1995	Military deminers	160	53 patients	Pressure mines (47%); Tripwire frag (34%)	Eye shield, goggles, helmet, panzer vest	Total extremity trauma (55%); head and facial trauma (38%).	Not reported	3.8% (2 deaths)	Quantitative scoring: Reported a mean Injury Severity Score (ISS) of 19.68 ± 8.57 (indicating "major trauma") and a mean Abbreviated Injury Scale (AIS) of 2.85 ± 0.6	Not reported	Bounding mines caused most severe injuries	Excludes uninjured workers
Harjai et al., 2007	India (Northern)	Military demining operations	Prospective analysis	Army Hospital records	2003–2004	Military deminers	~5000	35 patients	AP mine blast	Spider Boot‡; improvised visors	Eye trauma (85.7%); lower extremity trauma (14.3%—primarily closed calcaneal fractures).	0 with Spider Boot use	0	Comparative outcome: Reduced severity through specialized PPE; injuries were limited to closed calcaneal fractures and contusions, with no traumatic amputations or fatalities recorded	Not reported	Spider Boot drastically reduced injury	Early results; device paucity

(*Continued*)

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Table 1. (*Continued*)

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Smith (DDAS), 2019	Global	Humanitarian demining	Retrospective review	DDAS and insurance records	1995–2011	Civilian deminers	1 severe injury per 32 deminers per year	~1000 patients	Mines, ERW, and road traffic	Various; issues with incorrect usage	Severe upper extremity (hand/arm) and eye trauma.	Not reported	4 fatalities in medics	Predictive/ qualitative: Estimated frequency of one "severely injurious" accident per 32 field deminers every year	Not reported	Inadequate medical provision in 14% of cases	Commercial/ Political data withholding
Smith (DDAS), 2011	Global	Humanitarian mine action	Retrospective review	DDAS	1996–2011	Civilian deminers	Not reported	~1000 patients	AP blast mines most common	Ballistic body protective apron (STANAG 2920 V50 380 m/s)[§]	Severe upper extremity (hand/arm) and eye trauma.	Finger/hand loss mentioned	Higher with fragmentation	Not reported	Not reported	Management failings identified as primary cause	Relies on honesty of investigators
Smith (DDAS), 2002	Global	Humanitarian mine action	Retrospective review	DDAS	1996–2002	Civilian deminers	Not reported	~500 patients	AP blast mines (74%)	5 mm visors; blast hand tools	Upper extremity (hand/arm) trauma (42%); eye trauma (30%).	Fingers (11.5%); Hand (2.2%)	22% for AP blast	Clinical/ functional classification: Defines "severe" (requires surgical intervention or results in permanent disability) vs. "minor" (requires no surgical intervention and results in no long-term disability)	Not reported	Excavation is most common activity (46.5%)	Incomplete data capture (~65%)
Wyper, 2008	South Sudan	UN humanitarian demining	Descriptive review	UNMAO experience	2002–2008	Civilian deminers	Not reported	Not reported	Buried mines, road traffic	Eyewear and gloves	Not reported	Not reported	Not reported	Not reported; research focused on establishing national operational medevac standards and medical training	Not reported	Established national medevac plan	Policy focus over quantitative data

*Person-year = Statistical unit of measurement representing cumulative duration of time (in years) spent by all individuals in a group performing a specific activity, used to calculate and express incidence and mortality rates in standardized units (e.g., incidents per 100 000 workers per year) by accounting for fluctuations in the total population over a multi-year study period.

[†]P1 (Pattern 1) = An injury pattern caused by standing on a buried anti-personnel mine, typically resulting in the traumatic amputation of the foot or lower leg; P2 (Pattern 2) = An injury pattern caused by a fragment mine triggered near the victim, characterized by a random distribution of multiple fragment wounds; P3 (Pattern 3) = An injury pattern caused by handling a mine (such as during excavation, defusing, or children playing), characterized by severe upper extremity trauma and associated facial or eye injuries.

[‡]Spider Boot = A blast-protective footwear system designed to increase stand-off distance between the foot and a detonating anti-personnel mine, reducing blast energy transfer to the lower limb.

[§]NATO STANAG 2920 V50 (380 m/s) = NATO Standardization Agreement for ballistic (fragmentation) testing; V50 denotes the impact velocity at which there is a 50% probability of projectile penetration and 50% probability of non-penetration, used to characterize protective performance (here, 380 m/s).

document ISS, with others classifying injuries as either major/severe or minor.

Mechanisms of Injury

Anti-personnel mines were the most frequently reported mechanism of injury across six of the eight studies that documented device type. In the three studies reporting proportional data, handling AP mines was the predominant cause among humanitarian deminers, accounting for 51% of incidents in the HALO Trust dataset[10] and up to 74% of DDAS-recorded incidents.[16] Pressure-activated mines were more commonly implicated in the Croatian military demining context (47%); this was followed by tripwire-activated fragmentation mines (34%).[15] Coupland et al. showed that civilian and military injuries are more likely to arise from stepping on AP mines rather than handling them.[11]

Injury Patterns and Clinical Outcomes

Limb trauma was the predominant injury pattern across all eight included studies, with upper extremity injuries particularly characteristic of the demining population. In the two studies reporting proportional data for total extremity injuries, limb trauma accounted for 55% to 59% of all injuries.[10,15] The ICRC classification identified three characteristic injury patterns: lower limb amputations from standing on buried mines (Pattern 1); multiple fragment injuries to the head, chest, and abdomen (Pattern 2); and severe upper limb and facial trauma resulting from handling mines (Pattern 3).[11] Four percent of HALO injuries were too severe to be classified under the ICRC system, suggesting blast effects beyond those previously documented.[10,11]

Upper extremity and eye injuries were disproportionately represented in the demining population compared to other mine-affected groups. Brown et al. reported that deminers sustained upper limb and eye injuries in 62% of cases, compared with 4% among civilians injured by mines.[10] This pattern was consistent across all studies reporting anatomical injury distribution. In DDAS-derived data, upper extremity injuries accounted for 42% of all injuries and eye trauma for 30%.[16] The prevalence of eye injuries varied considerably across studies, reflecting differences in operational context and protective equipment. Among the general demining population, eye injuries were documented in 8% to 12% of casualties, most frequently associated with AP blast mines and commonly accompanied by severe upper limb injury.[16] A markedly higher proportion was reported by Harjai et al., in whose study eye trauma accounted for 85.7% of all injuries. This figure should be interpreted in the context of that study's evaluation of the Spider Boot, a blast-protective footwear system designed to reduce blast energy transfer, which reduced the relative proportion of extremity injuries, making ocular injuries the predominant recorded outcome.[17]

Amputation rates were reported in four of the eight studies, ranging from 0% among users of the Spider Boot system to 30% in the HALO Trust series and 66% among Indian military deminers operating without protective equipment.[10,17] Upper limb amputations, particularly of the fingers and hand, were most frequently documented in DDAS data, with finger loss accounting for 11.5% and hand loss for 2.2% of all injuries, respectively.[16]

Fatality rates were reported in five of the eight included studies, ranging from 0% to 22% depending on operational context, device type, and available medical support. Brown et al. reported a fatality rate of 15% among HALO Trust deminers, considerably lower than the 48% fatality rate reported among civilians injured by mines in the same period, attributed to faster evacuation and access to medical care.[10,18] The lowest mortality was recorded by Harjai et al., who reported 0 fatalities among Spider Boot users.[17] The highest fatality rate of 22% was documented for AP blast mine incidents in DDAS records.[16] Long-term occupational reintegration appeared limited, with only 20% of injured deminers in the HALO Trust series returning to work, a figure influenced by both the severity of injury and non-clinical factors such as insurance policy constraints.[10]

Protective Equipment and Injury Reduction

The introduction of protective equipment was associated with measurable reductions in injury severity. Following the implementation of mandatory full-face visors in 1995, the HALO Trust recorded a reduction in facial injury incidence from 327 to 214 per 100,000 workers per year.[10] The Spider Boot system, evaluated by Harjai et al., was associated with an absence of fatalities, amputations, or compound fractures among users, contrasting with a 66% amputation rate in those using conventional or no protective footwear.[17] Analysis from the Database of Demining Accidents (DDAS) suggested that procedural controls often conferred greater protective benefit than incremental increases in PPE alone, with strict adherence to standard operating procedures shown to substantially reduce injury risk. For example, DDAS records indicate that over 60% of severe upper-limb and eye injuries were associated with the misuse of standard digging tools at unsafe angles or distances, whereas fewer than 10% of such injuries could be attributed primarily to failures of PPE.[19]

Medical Support and Evacuation Challenges

Medical support provision varied considerably between operational contexts and directly influenced both survival and morbidity outcomes. Inadequate medical support was recorded as a contributory factor in 14% of DDAS-documented accidents.[13] In Sudan, the development of a national casualty evacuation plan that used United Nations Mission in Sudan (UNMIS) air assets, alongside the introduction of field medic protocols and targeted quality assurance training for medical teams, represented a model of improved response capacity. Wyper also highlighted the broader health care challenges faced by demining teams in Sudan, which included infectious diseases, limited surgical capacity, and the need for formal agreements with peacekeeping forces to guarantee air evacuation.[18]

Lessons from the Database of Demining Accidents (DDAS)

Findings from the DDAS have been used to identify systemic causes of accidents and shape revisions to the International Mine Action Standards (IMAS). Severe injuries were most frequently sustained to the hands, arms, and eyes, typically associated with improper tool use or inadequate protective equipment. Notably, failures in management, training, and operational leadership were identified more often than individual negligence as the primary causal factor.[16,19]

Smith reported that the DDAS was created to address the lack of a centralized cross-sector accident database and has since influenced safety guidelines globally, though completeness of reporting remains a major limitation. The database was later transferred to James Madison University (JMU) and renamed the Humanitarian Demining Accident and Incident Database. It has not been substantively updated since 2019, with only 3 entries recorded that year, raising concerns about its ongoing utility.[13]

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The Geneva International Centre for Humanitarian Demining has made parallel efforts to collect accident statistics by setting up the Mine Action Central Repository of Accidents (MACRA). However, this also has produced highly incomplete data, with only one injury reported across 2023 and 2024 combined, thereby limiting meaningful analysis.[20]

Discussion

This review set out to systematically identify and synthesize the existing evidence on injury patterns and clinical outcomes among adult humanitarian deminers, identifying three key findings. Firstly, deminers demonstrate a characteristic pattern of upper extremity and eye injuries that distinguishes them from other landmine-affected populations, driven by the handling mechanism of injury unique to clearance work. Secondly, the use and improvement of PPE have greatly reduced specific injury types over time. Thirdly, the evidence base underlying these findings is severely limited by incomplete, inconsistent, and largely historical reporting.

Across the included studies, the mechanisms of injury showed patterns distinct from those seen in other mine-affected populations. Mine-handling accidents accounted for a substantial share of cases,[10] whereas civilians and soldiers were more commonly injured after stepping on mines.[11] This difference reflects the unique exposures of clearance personnel and underlines the importance of prevention strategies tailored to manual demining. Similarly, highlighting the unique risk, fatality rates in humanitarian demining substantially exceed those reported in most other high-risk civilian occupations.[21] The reported injury patterns were consistent, with limb trauma dominating and high rates of amputation described.[10,15] Injuries to the eyes and face declined but did continue despite protective measures,[10,16] showing the limits of current equipment in shielding against fragments and blast effects. Provision of medical care should anticipate the need for upper limb and ophthalmic injuries and plan accordingly.

Protective equipment has had a measurable effect, particularly after the introduction of visors in the mid-1990s.[10] Even so, the literature indicates that PPE alone does not provide sufficient protection. Evidence from the Database of Demining Accidents (DDAS) points to the vital role of procedural controls such as correct tool use, safe working distances, and strong operational supervision in reducing injury.[19] A system-based approach integrating equipment, training, and leadership is more effective than relying on protective gear in isolation.

The level of medical support available was a key factor influencing outcomes. Poor evacuation and limited treatment capacity were linked with avoidable deaths and long-term disability,[13] while structured evacuation planning and the use of dedicated assets brought clear improvements.[18] Multiple casualty incidents, which occurred in a significant minority of cases, underline the need not only for formalized evacuation protocols but also for further analysis of evacuation timelines and how these influence survival and recovery.

Historically, accident databases have provided important lessons for the sector. The DDAS showed that failures in management, training, and operational oversight were more responsible for severe injuries than individual mistakes.[16,19] Despite this, there is a large gap in reporting incidents, resulting in incomplete and out-of-date datasets. Therefore, the opportunities to improve safety are reduced due to a limited evidence base to guide policy and practice.[13] This reflects the wider challenges with injury data collection in conflict-affected and humanitarian settings. In low- and middle-income settings where a high proportion of demining activity occurs, trauma registries are frequently incomplete or inactive.[22,23]

Limitations

Only a small number of studies met the criteria for inclusion, and most were published more than 20 years ago. This means that the available evidence may not reflect current demining practices, equipment, or patterns of contamination. The included studies varied widely in their design and the level of detail provided, which made direct comparison difficult. In several cases, key information—such as the type of mine involved, protective equipment used, or the medical support available—was missing or inconsistently reported. These gaps introduce the possibility of information bias, as important factors influencing injury severity may not have been captured.

Accident reporting within humanitarian mine action is known to be incomplete in many regions, and participation in databases such as the DDAS has always been voluntary. This likely creates reporting bias, with some incidents more likely to be recorded than others, and survivorship bias, as fatal or severe events may be either over- or under-represented depending on the system used. The lack of a reliable, contemporary global reporting mechanism also raises the possibility that the existing literature does not reflect the true range of injuries encountered in the field. The restriction to English-language publications may have introduced language bias, particularly given that significant demining activity and associated reporting occurs in non-anglophone regions. As this review relies on previously published material, the findings are subject to any publication bias or selective reporting present within those original sources. Finally, no formal review protocol was registered prior to conducting this review. Although the review adhered to PRISMA 2020 guidelines throughout, the absence of a registered protocol means the review process was not externally verifiable.

Conclusion

Humanitarian demining is a dangerous activity by its very nature, despite improvements in technology, training, and safety protocols. This review shows that deminers have consistent and characteristic injury patterns that are different from civilian and military mine victims. These results emphasize the importance of task-related risk, procedural control, proper personal protective equipment, and supervision in preventing occupational injuries.

The current state of the evidence base regarding injuries in deminers is limited and mostly historical relative to the evidence base for other mine-affected groups. This makes it difficult for mine action organizations to compare risk and assess the effectiveness of protection strategies. There is a critical need for the systematic collection and analysis of contemporary injury data to inform evidence-based strategies for improving occupational safety in humanitarian mine action.

Author contribution. The authorship criteria are set out by the International Committee of Medical Journal Editors (ICMJE). Blaise Hickson: conceptualization, literature searching, manuscript drafting, critical revisions, methodology; meets all four ICMJE criteria. Emma Lloyd: literature searching, manuscript drafting, critical revisions; meets all four ICMJE criteria. Kyung-Hoon Moon: critical revisions; meets all four ICMJE criteria. Timothy Gargan: conceptualization, literature searching; meets all four ICMJE criteria. Neil Eisenstein: critical revisions, supervision; meets all four ICMJE criteria.

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Ethical standards. This review synthesizes previously published data and did not involve human participants; therefore, ethics committee approval was not required.

Use of AI Technology Statement. Artificial intelligence tools were used solely for formatting tasks. No generative AI was used to create, analyze, or draft the scientific content. Details of AI use are disclosed in accordance with journal policy.

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