International Journal of Disaster Risk Reduction 77 (2022) 103090

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Medical students' education in disaster medicine: A systematic literature review of existing curricula

George T. Voicescu [a,b,*], Martina Valente [a], Francesco Della Corte [a], Marco Becerril [a], Luca Ragazzoni [a], Marta Caviglia [a]

[a] CRIMEDIM – Center for Research and Training in Disaster Medicine, Humanitarian Aid and Global Health, Università Del Piemonte Orientale, 28100, Novara, Italy

[b] Iuliu Hatieganu University of Medicine and Pharmacy, 8 Babes str., 400012, Cluj-Napoca, Romania

ARTICLE INFO

Keywords:
Disaster medicine
Disasters
Education
Undergraduate
Health education
Curriculum
Students
Medical

ABSTRACT

Disaster Medicine (DM) is currently underrepresented in medical schools' curricula worldwide, and existing DM courses for medical students are extremely heterogeneous due to the lack of pragmatic and standardized guidelines. Moreover, there is a gap in knowledge regarding the curriculum development methodology used for DM courses. This study aims to identify DM courses for medical students worldwide and to map their curriculum development methodologies by reviewing available literature. The search was conducted on three databases using terms "Disaster medicine" AND "Education". Following the PRISMA approach, twenty-five articles that described the content and implementation of DM curricula were included in the analysis. Nine studies thoroughly described the curriculum development process. Expert opinion and literature review were the methodologies mostly used to develop DM curricula. Only four studies followed a multi-method process made up of four different methodologies, including expert opinion, literature review, survey, and Delphi methodology. Most of the courses adopted a face-to-face approach combining different training modalities, including the use of virtual reality simulations and drills. Overall, this systematic review highlights the need for evidence-based educational curricula in DM and provides recommendations for developing DM courses following a scientific approach.

Abbreviations

DM	Disaster Medicine
AAMC	Association of American Medical Colleges
WADEM	World Association of Disaster and Emergency Medicine
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses

* Corresponding author. Stefan cel Mare Street, Nr 34B, Flat nr. 8, Săcele City, Brasov Country, 505600, Romania.
E-mail address: george.voicescu@uniupo.it (G.T. Voicescu).

https://doi.org/10.1016/j.ijdrr.2022.103090
Received 4 January 2022; Received in revised form 25 May 2022; Accepted 26 May 2022
Available online 29 May 2022

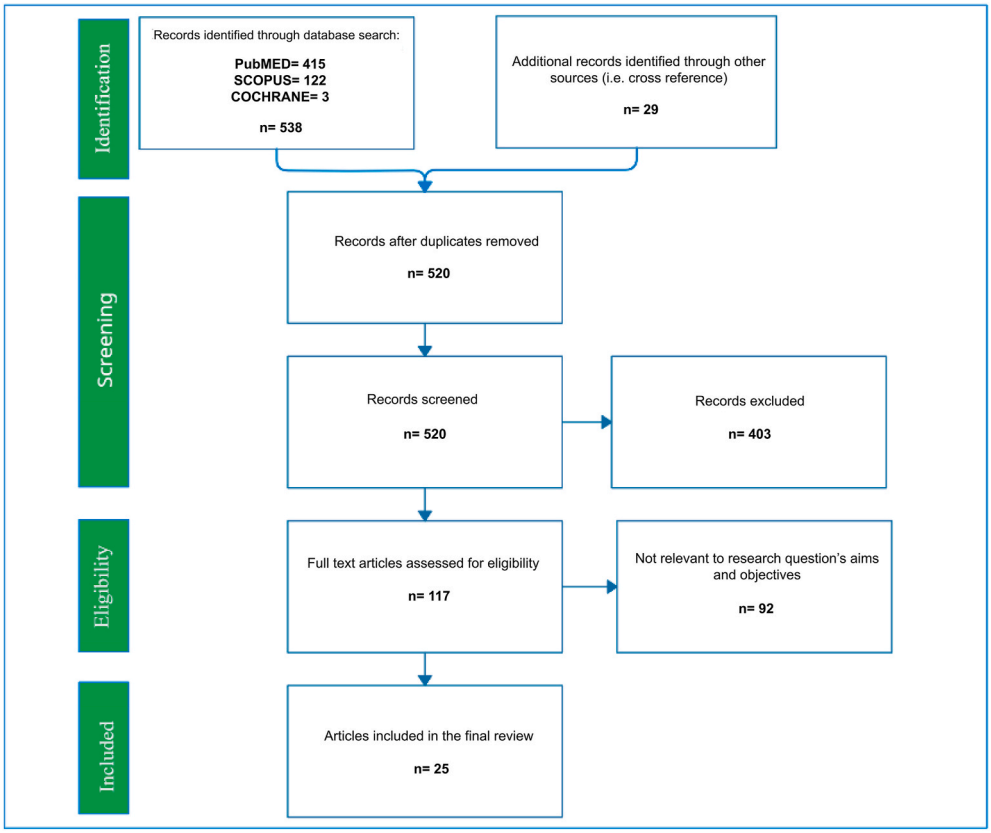

Fig. 1. PRISMA flowchart.

1. Introduction

In its first priority for action "Understanding disaster risk", the Sendai Framework for Disaster Risk Reduction 2015–2030 recognizes that promoting education and training activities in the field of disaster medicine (DM) is a fundamental component of disaster risk reduction [1]. At present, DM is not universally included in medical schools' curricula [2–4], and it appears that the competencies in DM are not considered essential within the educational path of a medical doctor. Rather, learning opportunities in DM are scant and mostly limited to postgraduate courses [5,6]. Consequently, disaster-related competencies are acquired only by those physicians who have personal interests in DM.

Although the COVID-19 pandemic has recently stimulated the academic community to consider introducing some basic DM teaching in medical school's curricula, the importance of DM education has been pointed out since the early 70s [7], and recognized by disaster and medical institutions since the early 2000s. In 2003, the Association of American Medical Colleges (AAMC) recommended that the medical schools integrate disaster response and mass casualty incident training in their curricula [8] and, one year later, the World Association for Disaster and Emergency Medicine (WADEM) directed efforts to develop minimum standards for DM education and training [9]. However, universities around the world have made scarce and sporadic progress towards including DM education in medical school's curricula [10–14].

In an historical moment when the awareness of the importance of DM is increasing, we should expect an increase of DM courses in the years to come. For this reason, it is necessary to systematize the scientific evidence on DM education by analyzing the different DM curricula and curriculum development methodologies reported in the published literature, and to identify the core DM topics and the methods that are predominantly used to develop DM courses.

The literature review recently conducted by Ashcroft et al. [15] highlighted the beneficial impact of medical students' disaster training programs on improving their knowledge, skills and attitudes. Nevertheless, despite being effective and well-received by learners, DM courses mentioned in the review appear to revolve around very specific aspects of DM, to contemplate very heterogeneous educational methodologies, and to be exposed to the risk of bias in their evaluation of outcomes, thus bringing forth the current lack of pragmatic and standardized guidelines to assist institutions in the development of DM curricula. However, the review did not address the variety of curriculum development methodologies employed by researchers to create such a diversified set of courses. Failure to consider the latter might disregard the scientific aspect of curriculum development and therefore undermine the quality of DM courses. In addition, Ashcroft and colleagues did not provide a detailed description of the topic included in each of the DM courses, thus neglecting important details that can inform curriculum developers.

Table 1
Curriculum development methodologies.

	Year of publication	*Experts panel discussion*	*Literature and/or web-based review*	*Survey*	*Delphi technique*	*Reliance on international guidelines or frameworks*
AAMC [8]	***2003***	***X***				
Bajow et al. [20]	***2015***	***X***	***X***	***X***		
Cummings & Della Corte [17]	***2004***		***X***	***X***		
Ingrassia et al. [11]	***2014***	***X***				***X***
Markenson et al. [18]	***2005***	***X***	***X***			
Pfenninger et al. [19]	***2010***	***X***	***X***	***X***		***X***
Scott et al. [21]	***2010***	***X***			***X***	
Scott et al. [23]	***2012***	***X***	***X***		***X***	
Subbaro et al. [22]	***2008***	***X***	***X***	***X***	***X***	

The aim of this systematic literature review was to identify available evidence of existing DM courses for medical students worldwide and to map the curriculum development methodologies, as well as courses' characteristics. Based on that, a list of recommendations is proposed to guide the development of future DM curricula through an evidence-based approach.

2. Methods

2.1. Search strategy

This study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) checklist (Fig. 1). A systematic literature review of articles reporting information on DM training and education courses for undergraduates was performed. The initial scanning and analysis of the included studies was performed by two independent investigators. The search was conducted in April 2021 on PubMed, Cochrane and Scopus using the MeSH Indexed Terms "Disaster medicine" AND "Education". After removal of duplicates, titles yielded by the search were manually scanned by two investigators independently and those not related to the aim were excluded. For the remaining articles, abstracts were further reviewed and those not complying with the inclusion criteria or meeting one or more of the exclusion criteria, were removed. For uncertain articles, full texts were screened. Additionally, the reference sections of the selected articles were revised to identify articles of relevance.

2.2. Eligibility criteria

Inclusion criteria consisted of English language articles that described the content and implementation of DM curricula at different levels (e.g., training programs, elective courses, workshops, lectures, or seminars) for medical students worldwide. Exclusion criteria embraced commentaries and articles dealing with courses and training targeting other categories of students than medical undergraduates.

2.3. Data extraction and analysis

Given the heterogeneity of the studies regarding whether or not they reported a description of the curriculum development methodology, a first distinction was made by identifying: (1) studies that describe the curriculum development methodology in such a comprehensive way that the study can be replicated, (2) studies that mention the methodology used for curriculum development but do not explain the details of the steps followed in practice, and (3) studies that only present the curriculum without a description of how it was developed. As for the studies that provided a thorough description of the curriculum development process, the methodologies employed to collect evidence and reach consensus on the curriculum items were identified and are reported in the results section. Classification of the studies was manually performed by two authors independently; discrepancies were resolved, and consensus was reached upon discussing with the research team.

When it comes to the analysis of the content of the curriculum, core DM topics identified by Sarin et al. [16] were used as a framework to map and systematize the thematic areas covered by the curricula of the studies included in this review. The set of core topics identified by Sarin et al. was chosen as a framework for data extraction because DM topics were agreed upon by a panel of experts, and because the authors deemed such topics comprehensive. Core topics identified by Sarin et al. [16] include, among others, Introduction to DM and Taxonomy, Health Consequences of Different Disasters, Triage, Prehospital Incident Management, Terrorism and CBRN Disasters.

Additional information was extracted from the studies to complement the findings and provide a complete overview of DM education - e.g., geographic distribution of the studies, teaching methods, trainers' background, student satisfaction, outcome of the course's evaluation, duration of the course, and number of students enrolled.

3. Results

3.1. Study characteristics

The initial screening of the three databases yielded 538 articles; 29 additional articles retrieved by alternative methods (e.g., cross reference) were added. Duplicate records from multiple database searches were removed manually. Twenty-five studies were included in this review, as outlined in the PRISMA diagram (Fig. 1). Eighteen of them described existing DM courses, while six were proposing

Table 2
Summary of findings. NM = not mentioned; MDEM = medical doctor with emergency medicine expertise; MDDM = Medical doctor with disaster medicine expertise; RRSim = Real size simulation; TTSim = Tabletop simulation; CASim = computer aided simulation; XVR = Virtual Reality simulation; CS= Case study.

Author	Year of publication	Country	Trainers	Training approach	Learning method	Course delivered	Mandatory/ optional	Number of course hours	Satisfaction (%)	Pre-course	Post-course	Number of trainees
AAMC [8]	2003	United States of America				No						
Back et al. [32]	2019	Germany	Military	Face to face	Theorethical CASim CS	Yes	mandatory	72	92	14	18	51
Bajow et al. [27]	2016	Saudi Arabia	MDDM	Face to face	Theorethical XVR CASim CS	Yes	optional	40	82.8	41	67.7	29
Bajow et al. [20]	2015	Saudi Arabia				No						
Cole et al. [36]	2016	United States of America	MDDM	Face to face	Theorethical RSSim TTSim	Yes	optional	16	100	NM	NM	14
Cowan & Cloutier [7]	1988	United States of America	Military	Face to face	Theorethical RSSim	Yes	mandatory	150	86	50	94	62
Franc-Law et al. [35]	2010	Italy	NM	Face to face	Theorethical CASim	Yes	optional	8	80	NM	NM	22
G. Cummings & Della Corte [17]	2004	Canada				No						
Ingrassia et al. [11]	2014	Italy	MDDM	Face to face Distance learning	Theorethical TTSim CASim CS	Yes	optional	17.5	98	3.95	8.29	20
Kaji et al. [25]	2010	United States of America	MDDM	Face to face	Theorethical RSSim TTSim CS	Yes	optional	40	100	NM	NM	6
Kaji et al. [37]	2010	United States of America	NM	Face to face	Theorethical RSSim	Yes	NM	4	86	NM	NM	43
Kim et al. [29]	2017	United States of America	NM	Face to face Distance learning	Theorethical RSSim	Yes	mandatory	32	84.8	NM	NM	402
Kommor et al. [10]	2019	United States of America	NM		Theorethical RSSim	Yes	optional	25	86.2	NM	NM	68

(*continued on next page*)

Table 2 (*continued*)

Author	Year of publication	Country	Trainers	Training approach	Learning method	Course delivered	Mandatory/ optional	Number of course hours	Satisfaction (%)	Pre-course	Post-course	Number of trainees
				Face to face Distance learning								
Markenson et al. [18]	2005	United States of America				No						
Parrish et al. [24]	2005	United States of America	Military	Face to face	Theorethical RSSim	Yes	mandatory	18	88	8.64	10.5	72
Patel & Dahl-Grove [30]	2018	United States of America	NM	Distance learning	Theorethical	Yes	optional	4	80	6	58	55
Pfenninger et al. [19]	2010	Germany				No						
Pollard et al. [26]	2015	United States of America	MDEM	Face to face	Theorethical RSSim	Yes	optional	NM	NM	NM	NM	52
Ragazzoni et al. [34]	2020	Italy	MDDM	Face to face Distance learning	Theorethical TTSim XVR CASim CS	Yes	optional	60	96	NM	NM	25
Scott et al. [21]	2010	United States of America	NM	Face to face	Theorethical RSSim CS	Yes	optional	3	97	39	58	68
Scott et al. [23]	2012	United States of America	NM	Face to face	Theorethical RSSim TTSim	Yes	optional	9	90	NM	NM	10
Subbarao et al. [22]	2008	United States of America				No						
Tsai et al. [33]	2020	Republic of China	MDEM	Face to face	Theorethical RSSim	Yes	NM	326	90	55.7	69	230
Wiesner et al. [31]	2018	United States of America	MDEM	Face to face	Theorethical TTSim CS	Yes	optional	24	NM	52.5	80	30
Yasui et al. [28]	2017	Japan				No						

DM curricula. Articles were published from 1988 to 2020 and covered several different countries (i.e., United States of America, Italy, Germany, Saudi Arabia, Japan, Canada, China) (Table 2).

3.2. Curriculum development

Of the 25 studies included, nine [8,11,17–23] described the curriculum development process in such a way that the study could be replicated, twelve [10,24–34] mentioned the methods that were used without an explanation of how these methods were implemented to develop the curriculum, and four [7,35–37] did not provide any description of the methodology used to develop the curriculum. Therefore, 16 of the included studies do not explain their curriculum development methodology in a replicable manner.

With regard to the nine studies thoroughly describing the curriculum development process, all except one [17] performed expert panel discussions to collect opinions from experts on the curriculum's objectives and topics, six studies [17–20,22,23] performed literature and/or web-based reviews to gain insight into DM education and collect information on existing courses and curricula, four [17,19,20,22] studies administered a survey and three [21–23] employed the Delphi methodology to reach a broader audience of stakeholders. Two out of nine studies [11,19] relied on international guidelines to develop the curricula. One study [22] followed a multi-method process made up of four different methodologies (i.e., experts panel discussions, literature review, survey and Delphi methodology), three studies [19,20,23] used three out of four methodologies, while the remaining studies [8,11,17,18,21] used either one or two methods to collect evidence for curriculum development (Table 1).

3.3. DM courses

The topics most frequently included in DM courses were Prehospital Disaster Preparedness (N = 20), Triage in Disasters (N = 20), Chemical, Biological, Radiation and Nuclear Disasters (N = 20) and Introduction to Disaster Medicine and Taxonomy (N = 19) (Table 3). In turn, concepts of Complex Humanitarian Emergencies were only included in two curricula (Table 3). Regarding the geographical distribution, Principles of Adult teaching, Complex Humanitarian Emergencies and Psychological Effects of disasters were more prevalent in Asia, while Terrorism and CBRN Principles were more prevalent in North America (Table 3).

The 18 courses were analyzed in terms of duration of the training, number of students and experience of the trainers. Five courses were shorter than 10 h [21,23,30,35,37], eight were between 11 and 50 h long [10,11,24,25,27,29,31,36], while four comprised over 50 h of training [7,32–34]. One study did not mention the duration of the training [26]. The number of students reached was heterogeneous as well, with three courses targeting less than 20 students [23,25,36], six targeting between 21 and 50 students [11,27,31,34,35,37], and nine targeting over 50 students [7,10,21,24,26,29,30,32,33].

Eleven courses mentioned the trainers' experience [7,11,24–27,31–34,36]. For five courses the trainers were medical doctors with disaster medicine experience [11,25,27,34], while in six cases the trainers had emergency medicine or military medicine backgrounds [7,24,26,31–33,36].

Regarding the teaching approach used, thirteen courses used a face-to-face approach [7,21,23–27,31–33,35–37], one course used a distance learning approach [30], while four courses combined the two approaches [10,11,29,34]. All courses used theoretical lectures. The practical training was delivered as full scale exercises and drills by eleven courses [7,10,21,23–26,29,33,36,37], tabletop simulations in six cases [11,23,25,31,34,36], computer aided simulations in five trainings [11,27,32,34,35], while two included virtual reality simulations [27,34]. In seven cases, the authors utilized case studies as teaching methods [11,21,25,27,31,32,34].

When it comes to the type of the course offered, twelve courses were elective programs [10,11,21,23,25–27,30,31,34–36], while four were mandatory classes [7,24,29,32]. Two studies did not mention the nature of the course [33,37].

Sixteen courses evaluated participants' satisfaction [7,10,11,21,23–25,27,29,30,32–37], while nine evaluated knowledge improvement among trainees [7,11,21,23,24,27,30,32,33]. Satisfaction of students was high, with a mean of 89.8 out of 100. All the courses reported improvement between the pre- and post-course tests (Table 2).

4. Discussion

This systematic review provides a comprehensive synthesis of available evidence on curricula and maps the main curriculum development processes used to develop DM courses targeting medical students. Results shed light on a great heterogeneity in the methodologies used to develop DM curricula, as well as in the topics covered by the courses and in course characteristics (e.g., duration, training approach, learning methods). Although cross-country differences in risk profiles, types of disasters and educational standards could justify this heterogeneity, the presence of official guidelines and the adoption of systematic evidence-based consensus building methodologies could ensure less fragmentation in DM education.

A course curriculum defines the foundations of the course and sets the core competencies that must be acquired by students. When it comes to the studies included in this review, it emerges that while some authors reported a detailed description of the methodology used to develop the course curriculum, others presented the curriculum without explaining how it was developed. This means that either the authors did not follow a structured methodology to develop the curriculum, or that they decided not to report the curriculum development methodology in their articles. In both cases the result is a gap in knowledge on how consensus has been reached on the topics included in the curriculum, which prevents replication of studies to develop curricula in other contexts.

When examining the studies that describe the curriculum development methodology, it is found that experts' panel discussions are frequently held to collect opinions of different stakeholders around the core DM competencies; these stakeholders typically belong to the academic field and have expertise in emergency medicine and education. Although experts' consultations enhance the collection of a multidisciplinary set of perspectives, the views of other important stakeholders, such as students, policymakers, educational administrators, employers or interest groups, have rarely been consulted and could have contributed to expanding the range of

Table 3
Curriculum topics.

Author	Introduction to Disaster Medicine/ Taxonomy	Health Consequences of Different Disasters	Triage in Disasters	Principles of Prehospital Incident Management	Hospital Disaster Mitigation, Preparedness, Response and Recovery	Complex humanitarian emergencies	Terrorism	CBRNE, Decontami-nation, PPE	Adult teaching	Communication	Psychological Effects	Ethical and legal matters	Government Organized and NGO Sponsored Response Teams	Disaster preparedness (surge capacity, risk assessment)	Public health during Disasters
AAMC [8]		x		x	x			x		x	x	x	x	x	x
Back et al. [32]		x	x	x				x			x		x	x	
Bajow et al. [27]	x		x	x	x	x			x		x			x	x
Bajow et al. [20]	x	x	x	x	x	x		x	x		x	x	x	x	x
Cole et al. [36]	x	x	x	x			x	x		x	x			x	
Cowan & Cloutier [7]			x					x		x					
Franc-Law et al. [35]	x	x	x	x											
G. Cummings & Della Corte [17]	x	x	x	x	x		x	x			x	x	x	x	
Ingrassia et al. [11]	x	x	x	x	x						x				x
Kaji et al. [25]	x			x			x	x			x	x	x	x	x
Kaji et al. [37]	x				x									x	
Kim et al. [29]	x		x	X			x	x		x		x			x
Kommor et al. [10]		x	x	x	x		x	x				x			
Markenson et al. [18]	x			x			x	x		x	x		x	x	x
Parrish et al. [24]	x	x	x				x	x		x	x	x	x		x
Patel & Dahl-Grove [30]	x		x	x				x				x	x	x	
Pfenninger et al. [19]	x	x	x	x	x		x	x		x	x	x	x	x	
Pollard et al. [26]	x		x				x	x							
Ragazzoni et al. [34]	x		x	x	x				x				x		
Scott et al. [21]	x		x	x				x		x					
Scott et al. [23]	x		x	x				x		x		x			
Subbarao et al. [22]	x	x	x	x				x		x	x	x	x	x	x
Tsai et al. [33]			x	x				x			x	x	x		
Wiesner et al. [31]	x	x	x	x	x		x	x		x	x	x	x	x	x
Yasui et al. [28]		x						x		x	x		x	x	x

Table 4
Recommendations.

CV development methodology	Learning methods
• Should be based on strong scientific evidence • Should be reproducible • Should comprise DM's transdisciplinarity [9] • Should follow the existing educational frameworks [9]	• A multimodal approach of theoretical lectures and interactive simulations should be used, for increasing students' engagement and knowledge retention [35, 61–63] • If organizing a full scale exercise would be out of reach, virtual reality or computer aided simulation should be used [48,49,58,61,64,65] • Predefined performance indicators should be used to evaluate students' performance [58]
Training approach	**Duration**
• A mixed approach, consisting of face to face and distance learning should be used [34,60]	• Elective DM courses should last 20–24 h organized in a 3-days course [34] • In case of time shortage, short courses (1 day) should be used [15]

perspectives, sharing ownership of the courses, and enhancing transdisciplinarity in the learning environment [38].

Alongside experts' panel discussions, other methodologies are used to collect systematic evidence for curriculum development, such as the Delphi methodology. The Delphi methodology consists in engaging different perspectives in reaching consensus on certain statements and allows for aligning views on specific propositions [39]. This methodology has already been used to design educational curricula and has proven effective for building consensus on professional standards and training methods [40–42].

Lack of reliance on standardized educational frameworks contributes to courses covering different topics and employing different formats to achieve their stated objectives. Although in 2004 the educational committee working group of the World Association for Disaster and Emergency Medicine (WADEM) drafted guidelines to set general standards on education and training on responding to disasters and emergencies that threaten people's health [9], only two of the included studies [11,19] refer to these guidelines, which suggests that they are not yet recognized as a universal framework for DM education. This is possibly due to their theoretical nature, which makes them scarcely useful at an operational level. Overall, the lack of reliance on universally accepted evidence-based educational standards, and the shortage of courses based on sound educational theory, remain important gaps to be filled in DM education.

The heterogeneity in the methodologies used to develop DM curricula is reflected in the heterogeneity of topics covered and course characteristics. Notwithstanding the content diversity, we have identified four recurrent topics present in almost every DM course included in this review, namely "Introduction to Disaster Medicine", "Triage in Disasters", "Principles of Prehospital Incident Management" and "CBRNE". These findings seem to suggest the possibility of introducing a standardized core of basic DM topics that could constitute the backbone of any DM course for medical students, enriched with additional themes selected according to the different needs, including course settings and local vulnerabilities, at the discretion of the providing institution.

The geographical distribution of the topics included in the courses follows the same distribution as the disasters. It is known that Asia is prone to humanitarian crisis, which explains the high prevalence of Complex Humanitarian Emergencies in the courses curricula [43].Terrorism was mainly included by the courses in North America, which is in accordance with the large public awareness and interest of the Americans in this topic [44].

Significant heterogeneity was also observed in the course duration. Although there are no formal recommendations regarding the length of a course, existing evidence shows that even short courses can be impactful on students' knowledge [45].

Of note, most of the courses identified have been delivered in the United States (US) [7,8,10,18,21–26,29–31,36,37] emphasizing the commitment of American Universities to comply with the recommendations elaborated by the American Council of Medical Education, and reiterated after the events of 9/11, to incorporate disaster medicine competencies in medical schools' curricula [8,46]. Although national recommendations suggest the inclusion of specific topics in the DM-related courses (e.g. bioterrorism and weapon of mass destruction), medical schools in the US are held responsible to develop their own training program and no specific guidance is available regarding the methods of delivery and course structure [46].

Taking into consideration the learning approach, studies identified ranged from traditional classroom lectures to multimodal approaches combining different training modalities, including the use of virtual reality simulations and drills. Although simulation training constitutes the cornerstone of DM education [47,48], the implementation of full scale exercises and drills, commonly recognized as the "gold-standard" for training disaster management competencies, could be impeded by high costs and low accessibility. To this extent, in the past years the use of virtual reality simulation has emerged as a valid cost-effective training alternative, with the potential to achieve a good degree of realism that allows trainees to practice inside an immersive scenario in a safe and controlled manner [49–54].

The question of whether the inclusion of simulation exercises in DM courses for medical students actually translates into better educational outcomes was recently addressed by the review published by Ashcroft and colleagues, who observed equal impact in terms of knowledge and skill improvement regardless of the training methodology adopted [15]. Nonetheless, a number of studies have abundantly highlighted that the adoption of a multimodal approach combining frontal lectures and interactive simulations has the potential to foster students' engagement and knowledge retention [35,55–57]. All this considered, there is a compelling need to aim for standardization in the design and assessment of the simulation exercises incorporated in the courses, with the option of integrating a series of predefined performance indicators to guide their development [58,59].

Lastly, it is noteworthy to underline the large use of the distance learning methodology in the provision of the identified courses, a

learning approach that has been successfully implemented in several disaster medicine courses for both undergraduates and post-graduates [34,57,60].

In conclusion, some limitations of this study are highlighted. First, this review has only collected articles in English. Other potentially useful studies in languages other than English may have been excluded from this review. Secondly, we did not go into any specific details pertaining to the model adopted in developing the curriculum (product and process models) or design (e.g. problem, learned or subject-centered), as it fell out of the scope of our review. Further research is needed to support curriculum developers in defining the best model and design to conceive DM training for undergraduates, taking into consideration the great variety of disciplines and topics included and the desired level of competences. A quality assessment of the included studies was not performed, and they were classified according to the presence/absence and accuracy of a description of the curriculum development process. As for the study's strengths, this review was conducted following a systematic process, with a rigorous and transparent approach to data retrieval, screening, and analysis. Three databases were considered, and no time limit was set to allow finding as much articles as possible. With the same goal, MeSH Indexed Terms were used to retrieve evidence.

5. Recommendations

The results of this review highlight the growing and urgent need to set standards for DM education for medical students worldwide. To support this effort, based on the findings of the present review, we provide recommendations for curriculum development (Table 4).

First, the curriculum development process should be based on strong scientific evidence and built using systematic methodology, which should be reported in scientific publications to ensure reproducibility. Whenever possible, relevant stakeholders within and outside academia should be consulted to enhance transdisciplinarity, and compliance to existing educational frameworks (e.g., WADEM guidelines) is advised.

Second, a mixed approach including traditional classroom sessions and distance learning could allow students to simultaneously experience cooperative activities, group work and social interaction in a conducive environment and benefit from the flexibility granted by the online methodology, having a course tailored around their own commitments, preferably both in an asynchronous and synchronous way.

Third, learning methods should entail a multimodal approach including both traditional and innovative educational methods, such as virtual reality simulations, to enhance students' interaction and knowledge retention. More broadly, the use of simulation from tabletop to computerized and full-scale exercises is advised, as well as the conduction of post simulation debriefing sessions to allow students to reflect on their performance through the analysis of performance indicators collected. Pre and post test evaluations are useful to detect knowledge retention, and assessment of students' satisfaction can guide the implementation of corrective measures and improvement of future courses.

Fourth, despite advising for the inclusion of DM courses in the Medical Curriculum, if delivered as elective courses, suggested duration of the course is 3 days (20–24 h). In case of time shortage, we advise for core subjects to be taught through a 1-day course.

6. Conclusions

This systematic review provides a compendious analysis of the curricula and curriculum development processes in DM training for medical students. The scarce usage of reproductible, comprehensive curriculum development methodologies and consequently a great heterogenicity of the covered topics and course design were brought forward. Therefore, there is a need for standardization in DM education. One possible strategy to reach this goal is the development of concrete educational frameworks, based on scientific evidence and sound research methodologies.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing 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.

Acknowledgments

This paper is supported by European Union's Horizon 2020 research and innovation programme under grant agreement N 786670, project NO-FEAR Network Of practitioners For Emergency medicAl systems and cRitical care.

References

[1] Sendai Framework for Disaster Risk Reduction 2015 - 2030. :37..

[2] L.J.M. Mortelmans, S.J.M. Bouman, M.I. Gaakeer, G. Dieltiens, et al., Dutch senior medical students and disaster medicine: a national survey [Internet], Int. J. Emerg. Med. (2015 Sep 3) 8. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4558995/. (Accessed 4 April 2020).

[3] H.E. Kaiser, D.J. Barnett, E.B. Hsu, T.D. Kirsch, et al., Perspectives of future physicians on disaster medicine and public health preparedness: challenges of building a capable and sustainable auxiliary medical workforce, Disaster Med. Public Health Prep. 3 (4) (2009 Dec) 210–216.

[4] T. Su, X. Han, F. Chen, Y. Du, et al., Knowledge levels and training needs of disaster medicine among health professionals, medical students, and local residents in shanghai, China, PLoS One 8 (6) (2013 Jun 24), e67041.

[5] R.R. Sarin, S. Cattamanchi, A. Alqahtani, M. Aljohani, et al., Disaster education: a survey study to analyze disaster medicine training in emergency medicine residency programs in the United States, Prehospital Disaster Med. 32 (4) (2017 Aug) 368–373.
[6] K.Y.A. Algaali, A. Djalali, F. Della Corte, M.A. Ismail, et al., Postgraduate education in disaster health and medicine, Front. Public Health 3 (2015) 185.
[7] M.L. Cowan, M.G. Cloutier, Medical simulation for disaster casualty management training, J. Trauma 28 (1 Suppl) (1988 Jan) S178–S182.
[8] The association of American Medical Colleges, Training Future Physicians about Weapons of Mass Destruction: Report of the Expert Panel on Bioterrorism Education for Medical Students, 2003. Available from: https://eric.ed.gov/?id=ED482377. (Accessed 29 March 2020).
[9] G. Seynaeve, F. Archer, J. Fisher, B. Lueger-Schuster, et al., International standards and guidelines on education and training for the multi-disciplinary health response to major events that threaten the health status of a community, Prehospital Disaster Med. 19 (2004 Feb 2) S17–S30.
[10] M.B. Kommor, B. Hodge, G. Ciottone, Development and implementation of a disaster medicine certificate series (DMCS) for medical students, Prehospital Disaster Med. 34 (2) (2019 Apr) 197–202.
[11] P.L. Ingrassia, L. Ragazzoni, M. Tengattini, L. Carenzo, et al., Nationwide program of education for undergraduates in the field of disaster medicine: development of a core curriculum centered on blended learning and simulation tools, Prehospital Disaster Med. 29 (5) (2014 Oct) 508–515.
[12] W.N. Naser, H.B. Saleem, Emergency and disaster management training; knowledge and attitude of Yemeni health professionals- a cross-sectional study, BMC Emerg. Med. 18 (1) (2018 Aug 6) 23.
[13] P.L. Ingrassia, M. Foletti, A. Djalali, P. Scarone, et al., Education and training initiatives for crisis management in the European Union: a web-based analysis of available programs, Prehospital Disaster Med. 29 (2) (2014 Apr) 115–126.
[14] R. Rezaee, M. Peyravi, M. Ahmadi Marzaleh, A. Khorram-Manesh, Needs assessment for standardized educational program for Iranian medical students in crisis and disaster management, J. Adv. Med. Educ. Prof. 7 (2) (2019 Apr) 95–102.
[15] J. Ashcroft, M.H.V. Byrne, P.A. Brennan, R.J. Davies, Preparing medical students for a pandemic: a systematic review of student disaster training programmes, Postgrad. Med. 97 (1148) (2021 Jun) 368–379.
[16] R.R. Sarin, P. Biddinger, J. Brown, J.L. Burstein, et al., Core disaster medicine education (CDME) for emergency medicine residents in the United States, Prehospital Disaster Med. 34 (5) (2019 Oct) 473–480.
[17] G. Cummings, F. Della Corte, Designing a curriculum in disaster medicine for Canadian medical schools, Int. J. Disaster Med. 2 (2004 Jan 1) 135–147.
[18] D. Markenson, C. DiMaggio, I. Redlener, Preparing health professions students for terrorism, disaster, and public health emergencies: core competencies, Acad. Med. J. Assoc. Am. Med. Coll 80 (6) (2005 Jun) 517–526.
[19] E.G. Pfenninger, B.D. Domres, W. Stahl, A. Bauer, et al., Medical student disaster medicine education: the development of an educational resource, Int. J. Emerg. Med. 3 (1) (2010 Feb 16) 9–20.
[20] N. Bajow, A. Djalali, P.L. Ingrassia, H. Ageely, et al., Disaster medicine curricula in Saudi Arabian medical schools, J. Emerg. Med. Trauma Acute Care 2015 (2015 Jan 1) 8.
[21] L.A. Scott, D.S. Carson, I.B. Greenwell, Disaster 101: a novel approach to disaster medicine training for health professionals, J. Emerg. Med. 39 (2) (2010 Aug) 220–226.
[22] I. Subbarao, J.M. Lyznicki, E.B. Hsu, K.M. Gebbie, et al., A consensus-based educational framework and competency set for the discipline of disaster medicine and public health preparedness, Disaster Med. Public Health Prep. 2 (1) (2008 Mar) 57–68.
[23] L.A. Scott, P.T. Maddux, J. Schnellmann, L. Hayes, et al., High-fidelity multiactor emergency preparedness training for patient care providers, Am. J. Disaster Med. 7 (3) (2012) 175–188.
[24] A.R. Parrish, S. Oliver, D. Jenkins, B. Ruscio, et al., A short medical school course on responding to bioterrorism and other disasters, Acad. Med. J. Assoc. Am. Med. Coll 80 (9) (2005 Sep) 820–823.
[25] A.H. Kaji, W. Coates, C.-C. Fung, A disaster medicine curriculum for medical students, Teach. Learn. Med. 22 (2) (2010 Apr) 116–122.
[26] A. Katherine, B.A. Pollard, J. Daniel, M.D. Bachmann, M.D. Marek Greer, P. David, Me Way, et al., Development of a disaster preparedness curriculum for medical students: a pilot study of incorporating local events into training opportunities, Am. J. Disaster Med. 10 (1) (2015 Jan 1) 51–59.
[27] N. Bajow, A. Djalali, P.L. Ingrassia, L. Ragazzoni, et al., Evaluation of a new community-based curriculum in disaster medicine for undergraduates, BMC Med. Educ. 16 (1) (2016 Aug 26) 225.
[28] K. Yasui, Y. Kimura, K. Kamiya, R. Miyatani, et al., Academic responses to fukushima disaster, Asia Pac. J. Publ. Health 29 (2_suppl) (2017 Mar) 99S–109S.
[29] T.E. Kim, T. Shankel, E.T. Reibling, J. Paik, et al., Healthcare students interprofessional critical event/disaster response course, Am. J. Disaster Med. 12 (1) (2017) 11–26.
[30] V.M. Patel, D. Dahl-Grove, Disaster preparedness medical school elective: bridging the gap between volunteer eagerness and readiness, Pediatr. Emerg. Care 34 (7) (2018 Jul) 492–496.
[31] L. Wiesner, S. Kappler, A. Shuster, M. DeLuca, et al., Disaster training in 24 hours: evaluation of a novel medical student curriculum in disaster medicine, J. Emerg. Med. 54 (3) (2018) 348–353.
[32] D.A. Back, V. Lembke, F. Fellmer, D. Kaiser, et al., Deployment and disaster medicine in an undergraduate teaching module, Mil. Med. 184 (5–6) (2019 May 1) e284–e289.
[33] Y.-D. Tsai, S.-H. Tsai, S.-J. Chen, Y.-C. Chen, et al., Pilot study of a longitudinal integrated disaster and military medicine education program for undergraduate medical students, Medicine (Baltim.) 99 (20) (2020 May 15), e20230.
[34] L. Ragazzoni, A. Conti, M. Dell'Aringa, M. Caviglia, et al., A nationwide peer-assisted learning program in disaster medicine for medical students, Eur. J. Emerg. Med. Off. J. Eur. Soc. Emerg. Med. 27 (4) (2020 Aug) 290–297.
[35] J.M. Franc-Law, P.L. Ingrassia, L. Ragazzoni, F. Della Corte, The effectiveness of training with an emergency department simulator on medical student performance in a simulated disaster, CJEM 12 (1) (2010 Jan) 27–32.
[36] L.A. Cole, B. Natal, A. Fox, A. Cooper, et al., A course on terror medicine: content and evaluations, Prehospital Disaster Med. 31 (1) (2016 Feb) 98–101.
[37] A.H. Kaji, W.C. Coates, C.-C. Fung, Medical student participation in a disaster seminar and drill: brief description of activity and report of student experiences, Teach. Learn. Med. 22 (1) (2010 Jan) 28–32.
[38] P. Taylor, How to Design a Training Course: A Guide to Participatory Curriculum Development, VSO, 2003, p. 170.
[39] S. Keeney, H. McKenna, F. Hasson, The Delphi Technique in Nursing and Health Research, John Wiley & Sons, 2010, p. 225.
[40] S.F. Fong, P.E. Ch'ng, F.P. Por, Development of ICT Competency Standard Using the Delphi Technique, 2013.
[41] H. Sitlington, A. Coetzer, Using the Delphi technique to support curriculum development, Educ. Train 57 (2015 Apr 13) 306–321.
[42] A.M. Martínez-Sánchez, Using the Delphi technique to determine objectives and topical outline for a pharmaceutical care course: an experience from the Cuban higher education system, BMC Med. Educ. 21 (2021 Mar 16) 158.
[43] Global Humanitarian Overview 2022 - World | ReliefWeb [Internet]. [cited 2022 May 21]. Available from:: https://reliefweb.int/report/world/global-humanitarian-overview-2022.
[44] M. Haner, M.M. Sloan, F.T. Cullen, T.C. Kulig, et al., Public concern about terrorism: fear, worry, and support for anti-muslim policies, Socius 5 (2019 Jan 1), 2378023119856825.
[45] B.D. Gable, A. Misra, D.M. Doos, P.G. Hughes, et al., Disaster day: a simulation-based disaster medicine curriculum for novice learners, J. Med. Educ. Curric. Dev. 8 (2021 Dec), 23821205211020750.
[46] D.E. Swee, Report of the Council of Medical Education Medical Students and Resident Involvement in Disaster Medicine and Public Health Preparedness Planning and Response [Internet], American Medical Association, 2011. Available from: https://www.ama-assn.org/sites/ama-assn.org/files/corp/media-browser/public/about-ama/councils/Council%20Reports/council-on-medical-education/i11-cme-med-student-resident-disaster-medicine.pdf. (Accessed 5 September 2021).
[47] W.C. McGaghie, S.B. Issenberg, E.R. Petrusa, R.J. Scalese, A critical review of simulation-based medical education research: 2003-2009, Med. Educ. 44 (1) (2010 Jan) 50–63.

[48] P. Luigi Ingrassia, L. Ragazzoni, L. Carenzo, D. Colombo, et al., Virtual reality and live simulation: a comparison between two simulation tools for assessing mass casualty triage skills, Eur. J. Emerg. Med. Off. J. Eur. Soc. Emerg. Med. 22 (2) (2015 Apr) 121–127.
[49] L. Ragazzoni, P.L. Ingrassia, L. Echeverri, F. Maccapani, et al., Virtual reality simulation training for ebola deployment, Disaster Med. Public Health Prep. 9 (5) (2015 Oct) 543–546.
[50] Y. Jung, Virtual reality simulation for disaster preparedness training in hospitals: integrated review, J. Med. Internet Res. 24 (1) (2022 Jan 28), e30600.
[51] M. Paquay, J. Goffoy, J.-C. Servotte, A. Ghuysen, Disaster medicine and virtual reality simulation: tracking down the factors impacting triage performance, Available from: https://orbi.uliege.be/handle/2268/260099, 2021. (Accessed 6 May 2022).
[52] M. Ferrandini Price, D. Escribano Tortosa, A. Nieto Fernandez-Pacheco, N. Perez Alonso, et al., Comparative study of a simulated incident with multiple victims and immersive virtual reality, Nurse Educ. Today 71 (2018 Dec 1) 48–53.
[53] N. Li, N. Sun, C. Cao, S. Hou, et al., Review on Visualization Technology in Simulation Training System for Major Natural Disasters [Internet], Nat Hazards, 2022 Mar 16, https://doi.org/10.1007/s11069-022-05277-z. Available from:. (Accessed 6 May 2022).
[54] B. Mills, P. Dykstra, S. Hansen, A. Miles, et al., Virtual reality triage training can provide comparable simulation efficacy for paramedicine students compared to live simulation-based scenarios, Prehosp. Emerg. Care 24 (4) (2020 Jul 3) 525–536.
[55] L. Carenzo, P.L. Ingrassia, F. Foti, E. Albergoni, et al., A region-wide all-hazard training program for pre-hospital mass casualty incident management: a real-world case study, Disaster Med. Public Health Prep. (2022 Apr 1) 1–20.
[56] L. Ragazzoni, A. Conti, M. Caviglia, F. Maccapani, et al., DisasterSISM: a multi-level blended learning program in disaster medicine for medical students, Prehospital Disaster Med. 34 (s1) (2019 May) s83–s83.
[57] S. Hermann, J. Gerstner, F. Weiss, S. Aichele, et al., Presentation and evaluation of a modern course in disaster medicine and humanitarian assistance for medical students, BMC Med. Educ. 21 (1) (2021 Dec 10) 610.
[58] D. Cohen, N. Sevdalis, V. Patel, M. Taylor, et al., Tactical and operational response to major incidents: feasibility and reliability of skills assessment using novel virtual environments, Resuscitation 84 (7) (2013 Jul) 992–998.
[59] A. Rüter, P. Örtenwall, T. Vikström, Comparison of an on-line information system with a conventional ambulance file system regarding the retrieval of information after missions, Int. J. Disaster Med. 3 (1–4) (2005 Jan 1) 37–40.
[60] F. Della Corte, I. Hubloue, A. Ripoll Gallardo, L. Ragazzoni, et al., The European masters degree in disaster medicine (EMDM): a decade of exposure, Front. Public Health 2 (2014) 49.
[61] D.S. Vincent, A. Sherstyuk, L. Burgess, K.K. Connolly, Teaching mass casualty triage skills using immersive three-dimensional virtual reality, Acad. Emerg. Med. Off. J. Soc. Acad. Emerg. Med. 15 (11) (2008 Nov) 1160–1165.
[62] W. Wilkerson, D. Avstreih, L. Gruppen, K.-P. Beier, et al., Using immersive simulation for training first responders for mass casualty incidents, Acad. Emerg. Med. Off. J. Soc. Acad. Emerg. Med. 15 (11) (2008 Nov) 1152–1159.
[63] S. Behar, J.S. Upperman, M. Ramirez, F. Dorey, et al., Training medical staff for pediatric disaster victims: a comparison of different teaching methods, Am. J. Disaster Med. 3 (4) (2008 Aug) 189–199.
[64] W.L. Heinrichs, P. Youngblood, P. Harter, L. Kusumoto, et al., Training healthcare personnel for mass-casualty incidents in a virtual emergency department: VED II, Prehospital Disaster Med. 25 (5) (2010 Oct) 424–432.
[65] P.B. Andreatta, E. Maslowski, S. Petty, W. Shim, et al., Virtual reality triage training provides a viable solution for disaster-preparedness, Acad. Emerg. Med. Off. J. Soc. Acad. Emerg. Med. 17 (8) (2010 Aug) 870–876.