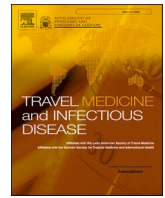




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Global mass gathering events and deaths due to crowd surge, stampedes, crush and physical injuries – Lessons from the Seoul Halloween and other disasters

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On October 29, 2022, a celebration night for Halloween in Seoul, South Korea, tens of thousands of revellers dressed in costumes crowded into the Itaewon district for the first unrestricted Halloween festivities since over two years of COVID-19 lockdowns. The large cumulative numbers of partygoers assembling in narrow streets with constrained access and exit points created a lethal combination. Videos taken over that night show people were trapped, crushed and unable to move or breathe, exacerbating panic that rapidly spiralled out of control. That resulted in one of the worst stampede disasters in South Korea, which caused 156 deaths and crush injuries in 170 [1]. Twenty-six of the deceased were from 14 countries, including the U.S.A, France, Thailand and Japan. Whilst the specific underlying factors leading to this tragedy is being determined; initial reports point towards inadequacies in pre and during-event planning, risk assessment, anticipated hazards, police response, and absence of effective rapid emergency response mechanisms, crowd management strategies and non-structural risk reduction measures. Whilst overcrowding, crowd surges due to unexpected events and stampede-associated crush injuries and deaths are well recognised as one of the most major non-communicable public health hazards at mass gathering events (Table 1), the South Korean Halloween night tragedy highlights that the current knowledge and understanding of these disasters is inadequate.

With the ease of travel, the world is experiencing an ever-increasing number of people travelling across continents to attend recurring mass gatherings due to sporting, religious, political, festive, and cultural events [2,3]. A review of a range of mass gathering events occurring globally (Fig. 1) shows that apart from extremes of temperatures and other weather-related events, the most common cause of mortality in mass gatherings are crush injuries resulting from overcrowding, crowd surges, crowd collapses and stampedes. In addition, environmental threats at mass gathering events, such as the collapse of infrastructures, fire incidents, terrorist attacks, and riots with violence, can all contribute to crowd panic, crowd surges, stampedes, restricted

movement and flow of people inducing crush injuries and death [4]. Even an initial minor altercation, accident or an unfounded rumour can trigger a local disturbance which can have a rippling effect with disastrous consequences. Besides high crowd densities and periodic surges, impulsive human behaviour and psychological responses complicate crowd control and management issues. Thus, determining underlying factors causing crowd disturbance is essential for ensuring the safety of attendees and local populations during mass gathering events. Current knowledge on underlying causes of rapid crowd surges, stampedes and crush injuries is mainly based on a small sample of large recurrent mass gatherings due to religious, sporting and festival events. However, risk factors identified from the study of past incidents, mostly at high profile annually recurring mass gathering events, have guided the development of basic frameworks and recommendations on hazard identification and execution of mitigation measures for human crowd surges, crowd chaos and stampede risk reduction and preventing crush injuries and deaths [5].

Up to 80% of stampedes recorded at mass gathering events in India have occurred during religious festivals [2]. The Kumbh Mela, the most significant religious MG held at four locations across India, involves over 100 million pilgrims bathing together in the holy rivers of Ganga, Godavari, Kshipra and Sangam at the confluence of Yamuna, Ganga and Saraswati [6]. Risk management strategies to tackle stampedes during these religious festivals remain inadequate and have failed consistently in India because of the large crowds and the constantly expanding geographical venues. Since the 2015 Kumbh Mela stampede, the risk of crush injuries, stampedes, and other mass casualty incidents, such as fires, have been minimised by close surveillance and constant evaluation of crowd flow [6]. Site preparation and negotiations with the various akharas (sects) to predetermine the order of ritual baths has resulted in a reduction in the number of deaths due to stampedes from about 500 people in 1954 to 37 in 2015 [6].

Crowd surge or stampede-associated crush injuries have been

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Table 1

Summary of Mass Gathering Events and Deaths due to Crowd surge, stampede and other physical disasters (1990–2022).

Mass Gathering	Type of Event	Date held	Location (City and Country)	Number of Deaths	Reference
Hajj	Religious MG	July 3, 1990	Mecca, Saudi Arabia	1426	[1]
Football Match	Sporting Event MG	13/1/1991	Orkney, South Africa	42	[2]
Football Match	Sporting Event MG	5/5/1992	Bastia, Corsica	17	[3]
New Year Celebration	New Year celebration MG	1/1/1993	Lan Kwai Fong, British Hong Kong	21	[4]
Hajj	Religious MG	23/5/1994	Mina, Mecca, Saudi Arabia	270	[1,5]
Mass Protest	Public Protest MG	23/11/1994	Nagpur, India	113	Web Reference [1] (https://www.indiatoday.in/magazine/special-report/story/19941215-morcha-of-gowaris-turns-into-bloody-stampede-claims-113-lives-810035-1994-12-14)
FIFA WC Qualifier	Sporting Event MG	16/10/1996	Guatemala City, Guatemala	83	[2]
Hajj	Religious	15/4/1997	Mina, Saudi Arabia	343	[1]
Hajj	Religious MG	9/4/1998	Mecca, Saudi Arabia	119	[1,5]
Sabarimala Temple Worship	Religious MG	14/1/1999	Sabarimala, India	52	[6]
Football Match	Sporting Event MG	9/7/2000	Harare, Zimbabwe	13	[7]
Roskilde Music Festival	Entertainment	30/6/2000	Roskilde, Denmark	9	[8]
Football Match	Sporting Event MG	11/4/2001	Johannesburg, South Africa	47	[9]
Fireworks show	Others	21/7/2001	Akashi, Japan	160	Web Reference [2] (https://www.cbsnews.com/news/crowd-crush-proves-fatal-in-japan/)
Football Match	Sporting Event MG	9/5/2001	Accra, Ghana	127	[2]
Hajj	Religious MG	5/3/2001	Mina, Mecca, Saudi Arabia	35	[1,5]
Hajj	Religious MG	11/2/2003	Mecca, Saudi Arabia	14	[1,5]
Hajj	Religious MG	1/2/2004	Mina, Saudi Arabia	251	[1,5]
Lantern Festival	Cultural MG	5/2/2004	Beijing, China	37	[8]
Bagdad Bridge Pilgrimage	Religious MG	31/8/2005	Bagdad, Iraq	965	[10]
Mandher Devi Temple Worship	Religious MG	25/1/2005	Wai, India	258	[11]
Hajj	Religious MG	12/1/2006	Mina, Saudi Arabia	456	[1,5]
Naina Devi Temple Worship	Religious MG	3/8/2008	Naina Devi, India	163	[11]
Football World Cup Qualifiers	Sporting Event MG	29/3/2009	Abidjan, Ivory Coast	19	[2]
Ram Janki Temple Worship	Religious MG	4/3/2010	Pratapgarh, India	63	[12]
Love Parade Music Festival	Entertainment- Music Festival MG	24/7/2010	Duisburg, Germany	21	[13]
Water Festival	Water festival MG	22/11/2010	Phnom Penh, Cambodia	347	[11]
Sabarimala Temple Worship	Religious MG	15/1/2011	Sabarimala, India	104	[6]
Halloween Celebration	Halloween festivities MG	1/11/2012	Madrid, Spain	5	[14]
New Year Fireworks	New Year celebration MG	1/1/2013	Abidjan, Ivory Coast	60	Web Reference [3] (https://www.bbc.com/news/world-africa-20881552)
Kumbh Mela	Religious MG	10/2/2013	Allahabad, India	36	[15]
Immigration Recruitment Tragedy	Others	15/3/2014	Nigeria	23	Web Reference [4] (https://guardian.ng/opinion/probe-of-immigration-job-tragedy/)
Shanghai New Year	Religious MG	31/12/2014	Shanghai, China	36	[16]
Hajj	Religious MG	24/9/2015	Mina, Saudi Arabia	769	[17]
Football UEFA Championship League	Sporting Event	3/6/2017	Turin, Italy	1	[18]

(continued on next page)

Table 1 (continued)

Mass Gathering	Type of Event	Date held	Location (City and Country)	Number of Deaths	Reference
Music Concert	Entertainment- Music Concert	26/6/2019	Antananariv, Madagascar	16	[19]
Ashura	Religious MG	10/9/2019	Karbala, Iraq	31	Web Reference [5] (https://www.bbc.com/news/world-middle-east-49653401)
Qasem Soleimani Funeral	Funeral MG	7/1/2020	Kerman, Iran	50	[20]
Jewish Festival	Religious MG	30/4/2021	Meron, Israel	45	[21]
Astroworld Music Festival	Entertainment-Music Festival	5/11/2021	Houston, USA	10	Web Reference [6] (https://www.theweek.in/news/entertainment/2021/11/15/astroworld-tragedy-what-happened-travis-scott-history-chaotic-concerts.html)
Africa Cup of Nations Football Match	Sporting Event MG	24/1/2022	Yaounde, Cameroon	8	Web Reference [7] (https://www.bbc.com/news/world-africa-60120367)
Football Match	Sporting Event MG	1/10/2022	East Java, Indonesia	135	Web Reference [8] (https://www.bbc.com/news/world-asia-63301863)
Music Concert	Entertainment- Music Concert	30/10/2022	Kinshasa, Democratic Republic of Congo	11	Web Reference [9] (https://www.timesnownews.com/world/eleven-die-in-stampede-at-fally-ipupa-concert-in-dr-congo-article-95189214)
Halloween Celebration	Halloween festivities MG	29/10/2022	Seoul, South Korea	153	Web Reference [10] (https://www.theguardian.com/world/2022/oct/29/dozens-of-people-crushed-by-large-crowd-at-halloween-festivities-in-south-korea)
Gay Nightclub	Social gathering	19/11/2022	Colorado Springs, USA	5	Web Reference [11] (https://news.sky.com/story/five-killed-18-injured-in-us-gay-nightclub-hate-attack-12751571)

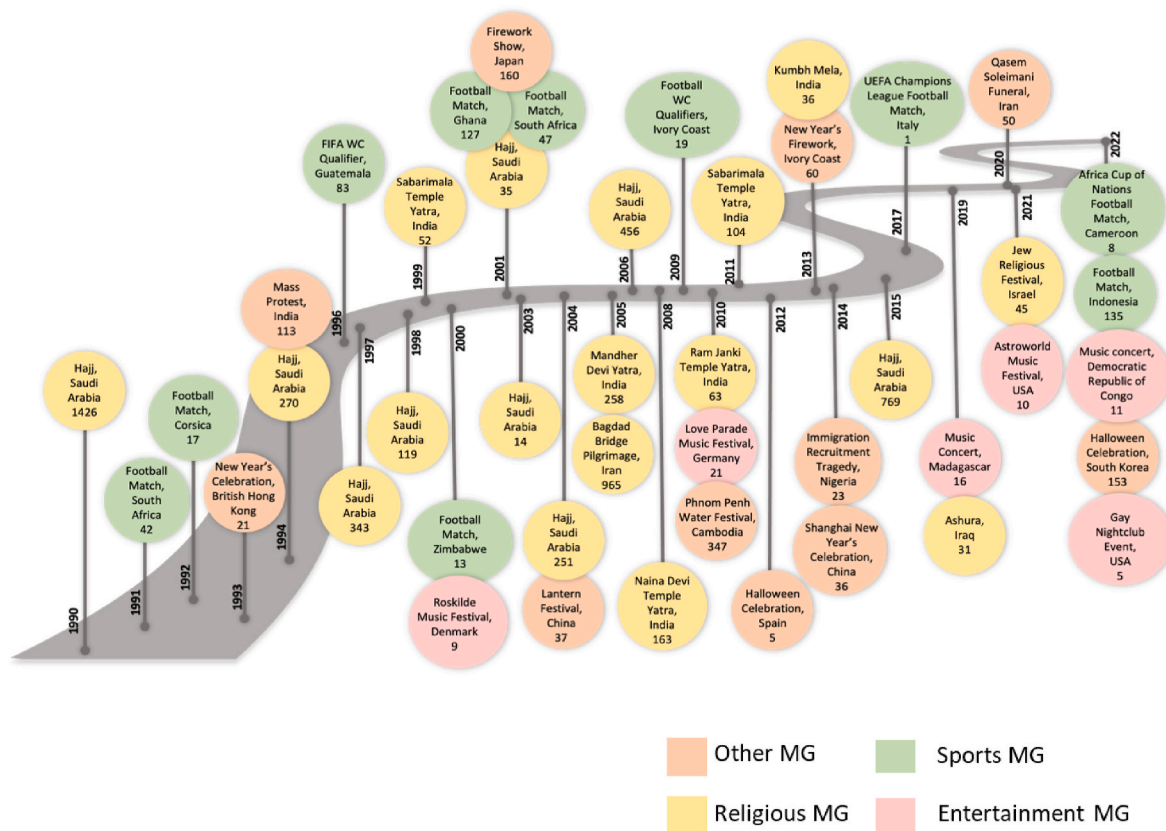


Fig. 1. Deaths due to crowd crush and other injuries at Global Mass Gathering Events over the past 32 years (1990–2022).

recorded at other recurring religious mass gathering events worldwide, such as the Arba'een (Iraq), Hajj (Saudi Arabia), Christmas and Easter Mass (Italy), Grand Magal of Touba (Senegal) and gay pride festivals (Global) (Table 1) [7,8]. During the 2015 Hajj pilgrimage, a major incident occurred, resulting in the deaths of pilgrims. On September 24, 2015, a significant crowd surge associated stampede occurred in Mina at the intersection leading up to the Jamarat Bridge [9]. This incident resulted in over 769 pilgrim deaths, the deadliest ever recorded at the Hajj. Since then, control measures such as crowd simulation models,

video monitoring, and modification of transport systems have been adopted in subsequent annual Hajj pilgrimages [9]. Other crowd management measures include increasing human or physical infrastructure to reduce the face-to-face meeting of the crowds in opposite directions by creating one-way paths for pilgrims, especially during Jamarat stoning, where most accidents are expected. The management also included increasing the human workforce to organise and direct pilgrims flow in their planned path.

The United Kingdom Hillsborough Stadium crowd collapse, crowd

crush and stampede disaster led to an enquiry which recently found event organisers guilty of deficiencies in planning and management [10]. This and studies of other crowd crush and stampede events have highlighted the multidimensional and multifactorial causality of these disasters, which are a consequence of a complex chain of events, arising from flaws in inadequate planning and preparedness preparation, organisation and execution of the mass gathering event, crowd mismanagement, miscommunication. Communication with the public during the event is essential since it plays a critical role in controlling the crowd and organising teams and volunteers [2,10]. Live surveillance of the crowd, if possible, will enable the monitoring of any pressure build-up, increase in crowd density, blockage of pedestrian movement; bottlenecks in traffic flow and identify the source of crowd disturbance early, enabling timely action via public and organiser communication [2,10]. Communication system management should pre-define the stage at which a public warning has to be issued for evacuation, who will be responsible for issuing the warning, and how the crowd will be informed with clear instructions without creating panic [2]. Once security systems and structures are in place, a mock exercise and tabletop exercise are required to ascertain the effectiveness of the function and responsibilities of the entire surveillance and monitoring system during the mass gathering event and in an emergency [2]. Regular briefings with key stakeholders will ensure that everyone knows the potential concerns and dangers, the emergency management plan and the response procedures, prior event training and simulation exercises for healthcare workers in managing mass casualties and injuries [2].

Despite multiple calls for universal systematic reporting and collation of comprehensive data on human crowd surges and stampede-related events, little progress has been made in achieving this goal globally. Without such detailed data, it remains challenging to gain better insight into mortality and injury rates, differences between sex and age groups, and factors associated with or underlying the occurrence and severity of the crowd surge and crush injuries disaster. Although current knowledge remains primarily based on a small sample of high-profile mass gathering events in high-resourced host countries, lessons can be learned and strategies tailored to fit low-income countries. The availability of literature on crowd management techniques and strategies from Hajj [11–14], the Olympics [15] and other mass gatherings [16] makes it easy for decision-makers and policy planners to plan for mass gathering events in their countries. Thus, the formulation of these evidence-based prevention strategies may not be applicable and generic to all mass gathering events. More research from different disciplines is warranted. To have a balanced evidence base, data from low-profile stampedes from lower-resource host countries are also required to tackle the complex and multifactorial aspects underlying these disasters. Despite increasing awareness of human stampedes, deaths from crush injuries still occur frequently and cause many fatalities, as highlighted by the Seoul Halloween disaster. Crowd surges, crowd panic, and stampedes are complex phenomena, and whilst there are several common factors, each event may have specific underlying factors. The time is now ripe for global public authorities to discuss how to formulate generic and event-specific, evidence-based, comprehensive risk reduction, prevention, and disaster management strategies. There remains an urgent need for a global effort to create an international standardised database that can record the human stampedes occurring globally in real-time.

Meanwhile, as with all mass gathering events [17,18], public health risks, sudden crowd rush, surge and crush events, including stampedes, should be anticipated and planned for, and crowd management should be a regular feature of emergency preparedness so that even with unplanned spontaneous MGs there will be some capacity and resilience in the local system to prevent or deal with minimal deaths.

Author contributions

All authors ideated the article. AZ and AS developed the first draft.

All authors contributed to writing and finalising the article.

Declaration of competing interest

Authors declare no conflicts of interest. All authors have an interest in travel medicine and mass gatherings. The views expressed are those of the authors and not necessarily of their respective institutions.

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Appendix A. Supplementary data

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References

- [1] Guardian The. At least 153 killed in crowd crush during Halloween festivities in Seoul. Available from: <https://www.theguardian.com/world/2022/oct/29/dozens-of-people-crushed-by-large-crowd-at-halloween-festivities-in-south-korea>, . [Accessed 31 October 2022].
- [2] Iliyas FT, Mani SK, Pradeepkumar AP, Mohan K. Human stampedes during religious festivals: a comparative review of mass gathering emergencies in India. *Int J Disaster Risk Reduc* 2013 September; 15:10–8. <https://doi.org/10.1016/j.ijdrr.2013.09.003>. Available from: .
- [3] Ngai KM, Burkle FM, Hsu A, Hsu EB. Human stampedes: a systematic review of historical and peer-reviewed sources. *Disaster Med Public Health Prep* 2009 Dec;3 (4):191–5. <https://doi.org/10.1097/DMP.0b013e3181c5b494>. Available from: .
- [4] Ahmed QA, Memish ZA. From the "Madding Crowd" to mass gatherings-religion, sport, culture and public health. *Trav Med Infect Dis* 2019 Mar-Apr;28:91–7. <https://doi.org/10.1016/j.tmaid.2018.06.001>. Available from: .
- [5] Soomaroo L, Murray V. Disasters at mass gatherings: lessons from history. *PLoS currents* 2012 February 2;4. <https://doi.org/10.1371/currents.RRN1301>. Available from: .
- [6] Memish ZA, Steffen R, White P, Dar O, Azhar EI, Sharma A, Zumla A. Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events. *Lancet* 2019 May 18;393(10185):2073–84. [https://doi.org/10.1016/S0140-6736\(19\)30501-X](https://doi.org/10.1016/S0140-6736(19)30501-X). Available from: .
- [7] Sharma A, Rodriguez-Morales AJ, Traore T, Shafi S, El-Kafrawi SA, Azhar EI, Zumla A. Globalisation of antibiotic-resistant bacteria at recurring mass gathering events. *Lancet* 2022 November 15. [https://doi.org/10.1016/S0140-6736\(22\)01995-X](https://doi.org/10.1016/S0140-6736(22)01995-X). Available from: .
- [8] Shafi S, Azhar E, Al-Abri S, Sharma A, Merali N, Al-Tawfiq JA, El-Kafrawi SA, Zumla A, Lee SS. Infectious diseases threats at the Arba'een-a neglected but one of the largest annually recurring mass gathering religious events. *Int J Infect Dis: IJID: Official Publication of the International Society for Infectious Diseases* 2022 Sep 12. <https://doi.org/10.1016/j.ijid.2022.09.010>. S1201-9712. Available from: .
- [9] Khan AA, Noji EK. Hajj stampede disaster, 2015: reflections from the frontlines. *American journal of disaster medicine* 2016 Jan 1;11(1):59–68. <https://doi.org/10.5055/ajdm.2016.0225>. Available from: .
- [10] de Almeida MM, von Schreeb J. Human stampedes: an updated review of current literature. *Prehospital Disaster Med* 2019;34(1):82–8. <https://doi.org/10.1017/S1049023X18001073>. Cambridge University Press, Available from: .
- [11] Felemban E, Rehman F, Biabani S, Ahmad A, Naseer A, Muhammad Abdul Majid AR, et al. In: Digital revolution for Hajj crowd management: a technology survey, vol. 8. IEEE Access; 2020. <https://doi.org/10.1109/AC-CESS.2020.3037396>. Available from: .
- [12] Alnabulsi H, Drury J. Social identification moderates the effect of crowd density on safety at the Hajj. *Proc Natl Acad Sci U S A* 2014;111(25):9091–6. <https://doi.org/10.1073/pnas.1404953111>. Available from: .
- [13] Shambour MK, Gutub A. Progress of IoT research technologies and applications serving Hajj and umrah. *Arabian J Sci Eng* 2022;47(2):1253–73. <https://doi.org/10.1007/s13369-021-05838-7>. Available from: .
- [14] Yamin M. Managing crowds with technology: cases of Hajj and Kumbh Mela. *Int J Inf Technol* 2019;11(2):229–37. <https://doi.org/10.1007/s41870-018-0266-1>. Available from: .
- [15] Bistaraki A, McKeown E, Kyratsis Y. Leading interagency planning and collaboration in mass gatherings: public health and safety in the 2012 London Olympics.

- Publ Health 2019;166:19–24. <https://doi.org/10.1016/j.puhe.2018.09.031>. Available from:
- [16] Hardcastle TC, Samlal S, Naidoo R, Hendrikse S, Gloster A, Ramlal M, et al. A redundant resource: a pre-planned casualty clearing station for a FIFA 2010 Stadium in Durban. *Prehospital Disaster Med* 2012;27(5):409–15. <https://doi.org/10.1017/S1049023X12000453>. Available from:
- [17] Yashio T, Murayama A, Kami M, Ozaki A, Tanimoto T, Rodriguez-Morales AJ. COVID-19 infection during the olympic and paralympic games tokyo 2020. *Trav Med Infect Dis* 2021;44:102205. <https://doi.org/10.1016/j.tmaid.2021.102205>. Nov-Dec, Epub 2021 Nov 13. PMID: 34785374; PMCID: PMC8590505.
- [18] Gallego V, Berberian G, Lloveras S, Verbanaz S, Chaves TS, Orduna T, Rodriguez-Morales AJ. The 2014 FIFA World Cup: communicable disease risks and advice for visitors to Brazil—a review from the Latin American Society for Travel Medicine (SLAMVI). *Trav Med Infect Dis* 2014 May-Jun;12(3):208–18. <https://doi.org/10.1016/j.tmaid.2014.04.004>. Epub 2014 Apr 25. PMID: 24821081.

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