



Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events

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Mass gathering events are associated with major public health challenges. The 2014 *Lancet* Series on the new discipline of mass gatherings medicine was launched at the World Health Assembly of Ministers of Health in Geneva in May, 2014. The Series covered the planning and surveillance systems used to monitor public health risks, public health threats, and experiences of health-care providers from mass gathering events in 2012 and 2013. This follow-up Review focuses on the main public health issues arising from planned mass gathering events held between 2013 and 2018. We highlight public health and research data on transmission of infectious diseases and antibiotic-resistant bacteria, mass casualty incidents, and non-communicable diseases, including thermal disorders. In the events discussed in this Review, the combination of a large influx of people, many from countries with outbreak-prone infectious diseases, with a high degree of crowd interactions imposed substantial burdens on host countries' health systems. The detection and transmission of antibiotic-resistant bacteria in pilgrims attending the Kumbh Mela and the Hajj raise concern of possible globalisation from mass-gathering religious events. Priorities for further investments and opportunities for research into prevention, surveillance, and management of these public health issues are discussed.

Introduction

A mass gathering is defined by WHO as a planned or spontaneous event that gathers substantial numbers of attendees who might strain the health planning and response capacities of the host community, city, or country.¹ Mass gatherings can present important public health challenges related to the health of attendees and of the host country population and health services.² The concept of mass gathering medicine as a specialty emanated from discourse on the 2009 Hajj, which was held during the 2009 H1N1 influenza pandemic (panel 1).³ The first International Conference on Mass Gatherings Medicine was held in Jeddah, Saudi Arabia, in October, 2010, where *The Lancet Infectious Diseases* Series on mass gatherings was launched (panel 1).⁴ This conference led to a coalition of experts from virtual WHO mass gathering collaborating centres and global academic and public health faculty⁵ to guide development of, and update, optimal public health and medical prevention and treatment guidelines at mass gathering events.^{6,7}

Mass gathering medicine as a new discipline was highlighted at the World Health Assembly of Ministers of Health in Geneva in May, 2014, where *The Lancet* Series on mass gathering medicine was launched.⁷ These state-of-the-art reviews covered the planning and surveillance systems used to monitor public health risks, public health threats, and experiences of health-care providers from three mass gathering events: the London 2012 Summer Olympics and Paralympics,⁸ the 2012 Union of European Football Associations European Championship finals,⁹ and the Hajj pilgrimages of 2012 and 2013.¹⁰ They set out the planning and surveillance systems used to monitor public health risks and described existing and potential public health threats (panel 2) and the experiences of health-care providers.

Mass gatherings events 2013–2018

Since the launch of *The Lancet* Series in 2014, various public health threats have continued to pose public health challenges for the planning of events and during events at various mass gathering events. This follow-up Review focuses on the main public health issues arising from planned religious, sporting, scouting, cultural, and musical mass gathering events held between 2013 and 2018: the Kumbh Mela 2013 and 2016 pilgrimages in India, the 12th Festival of Pacific Arts, the UN's Third Conference on Small Island Developing States, and the Micronesian Games in the Pacific Island Countries and Territories (PICTs), the Rio de Janeiro 2016 Summer Olympics and Paralympics, Russia 2018 FIFA World Cup, the 23rd World Scout Jamboree in Japan in 2015, and the annual Hajj pilgrimages of 2015, 2016, and 2017 in Saudi Arabia. We highlight public health and research data on transmission of infectious diseases, emergence of antibiotic-resistant bacteria, mass casualty incidents arising from stampedes and terrorist attacks, and non-communicable diseases, including heat-related

Search strategy and selection criteria

We searched PubMed, Embase, Cochrane Library, and Google Scholar for English language papers that were published from Jan 1, 2012, to Jan 1, 2019, with the terms "mass gathering" and "crowds" in combination with each of the following: "public health", "infectious diseases", "communicable diseases", "health services", "planning", "prevention" "vaccination", "immunisation", "sports", "religious", and "music". We also searched for publications by WHO, European Centre for Disease Control and the US Centers for Disease Control and Prevention, Saudi Arabian Ministry of Health and Ministry of Hajj websites, and Public Health England. We reviewed studies cited in articles identified in our searches and selected those that we identified as relevant.

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Panel 1: Historical evolution and formation of the mass gathering medicine specialty

- 2000–09: virtual networks on mass gathering events, collaborations on mass gatherings, and public health issues of importance to global health security. The concept of mass gathering medicine as a specialty emanated from discourse on the 2009 Hajj held during the 2009 H1N1 influenza pandemic
- Oct 23–25, 2010: the Jeddah Declaration on Mass Gathering Medicine was made at the Saudi Arabian Ministry of Health and *The Lancet Infectious Diseases* First International Conference on Mass Gatherings Medicine, held in Jeddah
- March 9–10, 2011: support for mass gathering medicine as a formal discipline at the 35th meeting of the Arab League health ministers
- Oct 2–5, 2011: endorsement at the WHO Regional Office for the Eastern Mediterranean meeting of health ministers in Cairo, Egypt
- January, 2012: reviewed and endorsed by the 130th WHO Executive Board meeting
- May 27, 2012: endorsement of mass gathering medicine by the WHO World Health Assembly 130th executive board
- September, 2012: WHO sets up the Global Centre for Mass Gatherings Medicine in Riyadh, Saudi Arabia, as a WHO collaborating centre
- Sept 21–23, 2013: Second International Conference on Mass Gatherings Medicine in Riyadh
- April 28–29, 2014: Third International Conference on Mass Gatherings Medicine in Riyadh
- May 27, 2014: formalisation of mass gatherings medicine as a new discipline at a forum held at the WHO World Health Assembly of Ministers of Health. This formalisation was twinned with the launch of the 2014 *Lancet* Series on mass gatherings medicine (which covered the 2012 Olympics and Paralympics in London, the 2012 Union of European Football Associations European Championship finals, and Hajj pilgrimages of 2012 and 2013)
- Oct 23–25, 2017: Fourth International Conference on Mass Gatherings Medicine in Riyadh
- Nov 22–23, 2018: Fifth International Conference on Mass Gatherings Medicine held in London

Panel 2: Health risks and hazards associated with mass gatherings

- Transmission of communicable diseases, including antibiotic-resistant bacterial infections
- Water and sanitation related disorders
- Non-communicable diseases and exacerbation of comorbidities (eg, diabetes, hypertension, COPD, and cardiovascular events)
- Mental health and psychosocial disorders
- Thermal disorders, including heat hyperpyrexia, heat stroke, heat exhaustion, and dehydration
- Stampedes
- Accidents, trauma, and crush injuries
- Terrorist incidents (biological and chemical warfare threats, explosives, and bombs)
- Alcohol and substance abuse

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disorders. Priorities for further investments and opportunities for research into prevention, surveillance, and management of communicable and non-communicable diseases, thermal disorders, and mass casualty incidents are discussed.

The Kumbh Mela

The Kumbh Mela, the Hindu religious pilgrimage festival, is the largest mass gathering event in the world,^{11–18} it attracts more than 120 million pilgrims from across the world for up to 2 months, and is held every 3 years alternately along the banks of four holy rivers: the Ganga, or Ganges, River (Haridwar district), Godavari River (Nasik district), Kshipra River (Ujjain district), and Sangam River (Prayag district, Allahabad) at a confluence of Ganga, Yamuna, and Saraswati. The 2013 Kumbh Mela event was attended by 70 million Hindu pilgrims over 55 days at the confluence of the Yamuna and Ganga Rivers.¹⁹

The Kumbh Mela is a highly coordinated and organised event, where WHO recommendations for mass gatherings are implemented (panel 3).^{1,2} The Indian Government and local authorities plan well ahead of each Kumbh Mela event and have established plans for physical and

public health infrastructure to be in place. So-called temporary pop-up cities that include tents for pilgrims, water pipelines and clean water supply, toilets, sanitation and sewage disposal facilities, vector control and surveillance teams, security services, and administrative assistance for pilgrims are set up along the river.^{20–22} A range of health-care facilities are put in place and hospitals are prepared to receive pilgrims requiring inpatient treatment and intensive care for every Kumbh Mela festival.²¹ Internal roads and pontoon bridges are built for these pop-up cities and are designed to streamline and facilitate pilgrim crowd movement and flow.²² State government irrigation and water resources departments and the Central Pollution Control Board work closely together to increase the capacity of sewage treatment plants and to ensure sufficient flow to remove contamination by releasing water into rivers.^{19,20}

90 000 kL/day of potable water were supplied for the 2013 Kumbh Mela for drinking and cooking, with 550 km of water pipelines were laid for distribution through 20 000 taps.¹⁹ Approximately 45 000 toilets were provided, although there was little health promotion messaging.²¹ Similarly to other mass gatherings, random inspection and vaccinations were done for immunocompromised individuals.²¹

Infectious diseases transmission at the Kumbh Mela

The Kumbh Mela is unique in that it involves frequent and prolonged bathing by pilgrims in the holy river, a ritual which is believed to break the cycle of reincarnations and convey immortality.^{17,18} Contamination of river water with faeces, urine, saliva, and sputa is inevitable and leads to transmission of waterborne and respiratory tract infections.^{12,14,20,21} A notable example of such a cycle of transmission is the 1817–24 Asia cholera pandemic, which was associated with the Kumbh Mela.²³ During the 2013 and 2016 Kumbh Mela ceremonies, in spite of toilets being available, pilgrims engaged in open defecation and

urination.²¹ Bacterial load in the river increased by approximately 130 fold.^{12,24–29} At the 2013 Kumbh Mela, a study^{15,16,20} that followed 30 000 pilgrims in four sector hospitals found a 5% incidence of diarrhoeal diseases over a 23-day period. A rise in non-bloody diarrhoea cases was seen just 2 days after the main bathing day on Jan 29, 2013, and a peak in upper respiratory tract infections coincided with the peak in non-bloody diarrhoeal disease. The use by pilgrims of fires fuelled by cow dung or firewood resulted in more than 23% seeking cough medicine and smoke from choolahs using wood or coal was the commonest cause of respiratory illnesses among 15 000 patients.¹³ The observation that a so-called shaving ritual could increase the risk of bloodborne disease transmission has not yet been confirmed, because the practice is surrounded by secrecy and there is little of information on how widespread it is.¹³

Emergence and transmission of antibiotic-resistant bacteria at the Kumbh Mela

The presence of extended-spectrum β -lactamase-producing *Escherichia coli* in municipal sewer systems and waste water in Hyderabad, India, have sparked concerns that antibiotic-resistant bacteria could be spreading at mass-gathering religious events.²⁶ The rivers of India are known to be polluted owing to inadequately treated household and industrial effluents.^{26,27,29} A 20 times increase in *bla*NDM-1 gene carrying bacteria during the pilgrimage on the bank of the Ganges was observed during the 2015 Kumbh Mela.²⁷ A novel antibiotic-resistant bacterial species, *Corynebacterium godavarianum*, has been isolated from the bathing site of the Godavari River.²⁵ In response to this growing global concern,²⁸ an expert panel concluded that use of antibiotics should be restricted to acute travellers whose diarrhoea is incapacitating.³⁰

Stampedes at the Kumbh Mela

Since the stampede at the Kumbh Mela in 2015,²² 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. 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 (table).²²

The Festival of Pacific Arts and the Micronesian Games

The Festival of Pacific Arts and the Micronesian Games are a feature of PICTs.^{38,39} Although several of the event host countries have a population under 200 000, such as Yap State (population 11 000) in the Federated States of Micronesia that hosted the 9th Micronesia games in July 2018, the health security risks remain the same, and can be proportionally greater, than similar events in larger countries, due to the influx of people and its effect

Panel 3: Key considerations related to communicable disease alert, response, and operation plans for mass gatherings

- Risk assessment and management, surveillance and alert systems, and outbreak alert and response twinned to effective communication strategies
- Rapid identification of attendees with communicable diseases and their contacts for potential quarantining and instituting preventive infection control measures
- Medical care planning and guidelines (preventive medicine, mandatory vaccinations, food management, water and waste management, and identification of physical and fire hazards)
- Public health measures (water protection and provision, food protection and provision, and syndromic surveillance)
- Emergency planning and response (rapid access to injured or ill patients, provision of triage in the field and at aid stations, provision of on-site care for minor injuries and illnesses, effective and timely stabilisation and transport of patients requiring evacuation)
- Disaster medicine, trauma, and triage and level of care
- Mobile units, health stations, and designated hospitals
- Use of modern technologies for proactive surveillance, early diagnosis and rapid detection, data collection, analyses, sharing, and communication.
- Updating travel guidelines, including vaccinations, for each specific mass gathering event

on the fragile health infrastructure of PICTs. Three enhanced surveillance activities for mass-gathering events in PICTs occurred during national or regional disease outbreaks that had the potential to severely affect the mass gatherings, place greater strain on health services, and cause substantial tourism-related economic and reputation loss.

The Eighth Micronesian Games took place in Pohnpei State, Federated States of Micronesia, in July, 2014.³⁸ Pohnpei is a small island state of around 36 000 people in the western Pacific. The Games attracted about 1700 athletes and officials from several Micronesian countries and territories. In June, 2014, 6 weeks before the opening of the Games, Pohnpei reported the first case of measles in an outbreak that spanned the duration of the Games and the following 3 months and resulted in a total of 251 cases.⁴⁰

The UN's Third Conference on Small Island Developing States was held in Apia, Samoa on Sept 1–4, 2014.⁴¹ Attracting more than 3000 delegates from 115 countries, it was the largest event ever to be hosted by Samoa, a Polynesian island nation in the south Pacific with a population of around 187 000. In late July, 2014, an extensive chikungunya virus disease outbreak began in Samoa that resulted in more than 4000 cases 4 months later.⁴²

The 12th Festival of Pacific Arts was hosted by the Micronesian island of Guam (population 163 000) in 2016.⁴³ The Festival was a large event, attracting more than 2500 artists and performers from 27 countries and territories across the Pacific. These island communities (some very small, such as the Pitcairn Islands with fewer than 50 residents) would have been greatly affected by the introduction of a novel disease. The Festival was held

	Date	Disaster type	Casualties
Hajj ²¹	Sept 11, 2015	Crane at building site collapsed onto the Grand Mosque in Mecca	107 pilgrims died and 394 injured
Hajj ²²	Sept 24, 2015	Stampede in Mina at the intersection leading up to the Jamarat Bridge	769 pilgrims died and 934 injured
Kumbh Mela ²¹	2013	Stampede at railway station	37 pilgrims died
Kumbh Mela ²²	2015	Stampede on the banks of the river Godavri	27 pilgrims died
Boston marathon ³³	April 15, 2013	Terrorist bomb attack—two improvised pressure cooker explosive devices	3 people killed and 264 injured
Shanghai New Year celebrations ³⁴	Dec 31, 2014	Stampede between Chenyi Square and the platform of the Bund	36 people died and 116 injured
Bataclan theatre, Paris ³⁵	Nov 13, 2015	Mass shooting and suicide bomb at Eagles of Death Metal concert	90 people killed and 413 injured
Manchester music concert (singer Ariana Grande) ³⁶	May 22, 2017	Suicide bombing—explosive device in the entrance foyer area of Manchester arena	23 people killed and 139 injured
Las Vegas outdoor Route 91 Harvest music festival in Nevada ³⁷	Oct 1, 2017	Mass shooting by a gunman perched on the 32nd floor of a nearby Las Vegas hotel	58 people killed and 851 injured

Table: Mass casualties at mass gathering events (2013–18)

while Zika, dengue, chikungunya, and measles outbreaks were occurring in several participating countries.^{40,42,44,45}

At all these mass gathering events, the combination of large influxes of people and high degrees of social mixing in the presence of highly infectious pathogens, emerging non-vaccine-preventable diseases, and diseases with incurable long term consequences (eg, Zika birth defects) could have introduced substantial population burdens and consequences for health systems. To counter these threats, enhanced surveillance for these mass gathering events was essential to ensure health security.^{41,46}

The three events used enhanced syndromic surveillance that built on the existing pan-Pacific WHO-led weekly syndromic surveillance,⁴⁷ ensuring host countries were prepared. However, although short, the period of intense activity that characterises mass gathering surveillance is a substantial burden to stretched local public health resources. To alleviate this burden additional support was gained from within host countries and from external partners provided by the Pacific Community, which has extensive experience of mass gathering surveillance, and the Pacific Island Health Officers Association.

Mass-gathering surveillance in the Pacific has shown the value of a strong foundation in existing disease surveillance and of regional partnerships. These two aspects were essential in host countries' ability to implement comprehensive and intensive mass-gathering surveillance. However, although the benefit of early-warning disease surveillance was established, longer-term sustainable surveillance improvements were harder to realise. For example, local public health departments borrowed personnel from other departments and external support, all of whom returned to their previous duties once the mass-gathering surveillance finished.

The mass-gathering surveillance was successful^{46,47} on all three occasions and showed that even small nations can (with the right support) provide health security in the face of substantial health risks. In doing so, these events proved the value of the mass gathering surveillance in providing health security assurance to event organisers, participants, and local and regional communities as well as showing that small island nations can meet

International Health Regulations requirements and implement enhanced mass-gathering surveillance.

The Rio de Janeiro 2016 Summer Olympics and Paralympics

Various public health concerns were raised before the Rio de Janeiro Olympics and Paralympics in August, 2016.^{48–51} In February, 2016, WHO declared the Zika virus a public health emergency of international concern owing to the Zika outbreak in Brazil and its association with birth defects.⁵⁰ There was global pressure for the Games to be either postponed or moved to another country.⁵²

The WHO Emergency Committee on Zika virus decided that postponing or cancelling the Games had no public health justification,^{49–51,53} stating that “individual risks in areas of transmission are the same whether or not a mass gathering is conducted, and can be minimised by good public health measures”.⁵⁰ Because Brazil is a dengue-endemic country, the risk of dengue to non-immune visitors was also a concern,⁵⁴ based on the experience from a pilgrimage in Senegal⁵⁵ and from GeoSentinel data. GeoSentinel is a global network of travel medicine providers focused on sentinel surveillance, which generates evidence-based assessments of infectious disease risks for attendees of future mass gatherings events.^{56,57}

As with the 2012 Olympics and Paralympics in London,¹⁸ WHO provided technical support to the Brazilian Ministry of Health and International Olympic Committee to ensure public health safety during the Games. This support included improving the quality of water for recreation and preventing the spread of Zika virus by increasing vector control efforts. In spite of intensive media coverage, no cases of Zika virus were confirmed among people who attended, both during the Games and since returning to their home countries.^{50,58,59} Having a strong risk communication systems and a firm evidence-based risk management strategy is key to resisting media and political pressure. Further discussion and debate is required on the ethical principle of social responsibilities of organising mass

gathering events during infectious disease outbreaks with epidemic potential.⁶⁰

Before the 2016 Summer Olympics, another concern was related to water sports and athletes being exposed to polluted waters.⁶¹ However, a study⁶¹ done during tests in 2015 showed no increased incidence of diarrhoea among exposed individuals compared with controls. When travellers to the 2014 FIFA World Cup in Brazil were compared with other travellers to Brazil during the same period, the majority in both groups were bitten by insects and had sunburns as environmental risk factors, and every third traveller suffered from diarrhoea.^{58,61} Men travelling to the World Cup tended to have more sexual contacts outside of a relationship than a control group of other travellers to Brazil and also had more alcohol intake.⁴⁸

Russia 2018 FIFA World Cup

The 2018 FIFA World Cup was hosted by Russia between June 14 and July 15, 2018.⁶² The event was attended by 3 million people with 32 international teams participating in 64 football matches in 12 stadiums across 11 cities: Ekaterinburg, Kaliningrad, Kazan, Moscow, Nizhny Novgorod, Rostov-on-Don, Saint Petersburg, Samara, Saransk, Sochi, and Volgograd.⁶² Data from WHO's Regional Office for Europe⁶² showed that the Russian Federation had reported 454 isolates from blood and cerebrospinal fluid samples from urban tertiary care hospitals across the country before the event. Carbapenem resistance occurred in 74% of *Acinetobacter* spp isolates, 49% of *Pseudomonas aeruginosa* isolates, and 12% of *Klebsiella pneumoniae* isolates. 23% of *Staphylococcus aureus* isolates were methicillin-resistant and 91% of *K pneumoniae* isolates were resistant to third-generation cephalosporins. Although no reported major public health incidences were reported, the 2018 FIFA World Cup created heightened awareness of the threat of the transmission and globalisation of antibiotic-resistant bacteria. No cross-sectional or longitudinal cohort studies from the event have been published.

The 23rd World Scout Jamboree

The 23rd World Scout Jamboree was hosted by Japan between July 28 and Aug 8, 2015, and was attended by 33 000 scouts of up to 17 years of age from 162 countries.⁶³ The World Scout Jamboree is an international Scout Movement camp. It takes place every 4 years, with the site of the Jamboree rotating between continents. The daily schedule includes arduous activities, such as climbing, woodchopping, and knife handling, and preparing one's own meals on gas stoves. Apart from risk of transmission of infectious diseases, injuries, and burns, it induces a range of psychological disorders, including homesickness and behavioural and neuropsychological disorders.⁶⁴

No major infectious diseases outbreaks were reported during the Jamboree. However, within 9 days of the end of the event, six cases of laboratory-confirmed invasive

meningococcal disease caused by *Neisseria meningitidis* capsular serogroup W occurred among scouts and their close contacts in Scotland and Sweden.⁶⁵⁻⁶⁷ Soon after return to Scotland, three scouts and one relative were diagnosed with invasive meningococcal disease. These cases were all associated with one scout unit. Two confirmed cases of invasive meningococcal disease were reported from Sweden.⁶⁵ Molecular analysis⁶⁵⁻⁶⁷ showed that the same *N meningitidis* isolates were responsible for the six cases and that they belonged to the ST-11 clonal complex, which is usually associated with large outbreaks. No other cases were reported from scouts who attended from other European countries or Japan. All participants were made aware of the outbreak and of signs and symptoms of invasive meningococcal disease through an information campaign and were offered ciprofloxacin chemoprophylaxis.^{66,67} To make a decision on the need for prophylactic treatment for close contacts of returning scouts, throat or nasopharyngeal swabs from participants receiving antibiotic prophylaxis were taken. The carrier state in Swedish teenagers was studied comparing sensitivity of throat versus nasopharyngeal swabs from 1020 of the 1890 Swedish teenagers who participated in the Jamboree. The overall positivity for *N meningitidis* in this group was 83 (8%) of 1020, of which 61 were non-groupable.⁶⁷ Further carriage studies are required during mass gatherings to determine the epidemiology and association between carrier isolates and disease-causing isolates in the population and the dynamics of globalisation from mass gathering events.

The Hajj annual pilgrimages—2015, 2016, and 2017

Every year an increasing number of people travel to Saudi Arabia for the Hajj and Umrah pilgrimages.⁶⁸ The total number of pilgrims for both the Hajj and Umrah is about 10 million pilgrims annually from more than 180 countries. The Hajj pilgrimages that took place in 2015, 2016, and 2017 each attracted more than 2 million people from outside Saudi Arabia.⁶⁸ Several major public health challenges are associated with each Hajj,¹⁰ including transmission of infectious diseases, exacerbation of non-communicable diseases, mental health disorders, and stampedes (appendix), among others. Infectious diseases surveillance systems are operational during the annual Hajj, and they have evolved from paper-based reporting tools to automated electronic systems, recording and storing large datasets, and reporting from mobile units, clinics, primary health facilities, and hospitals that serve pilgrims.¹⁰ All these data are fed directly to a central command and control unit, enabling rapid amalgamation and analyses of data and necessary public health interventions. These advances in real-time surveillance have improved public health security for the mass gatherings at the Hajj.⁶⁹

See Online for appendix

Infectious diseases at the Hajj

In the past 5 years, concern has grown with regard to the threat to global health security posed by several emerging and re-emerging infectious diseases. Because of the Ebola outbreaks in West Africa (2013–16),⁶⁹ the cholera outbreak in Yemen (2015–18),⁷⁰ Zika virus in the Americas and south-east Asia (2016–18),^{49–51} Lassa fever in Nigeria (2018),⁷¹ diphtheria in Venezuela (2016–17)⁷² and Yemen (2017–18),⁷³ Yellow fever in Latin America and Africa (2016–18), and Nipah virus in India and south Asia (2017–18),⁷⁴ concerns were expressed by the global public health fraternity regarding pilgrims from affected countries travelling to Saudi Arabia for the Hajj or Umrah.⁷⁰ The Saudi government implemented restrictions only to countries affected by the Ebola outbreak. For pilgrims from Yemen and other countries, intensified screening at points of entry into Saudi Arabia and close surveillance during their stay throughout the Hajj, was implemented, with no cases detected.⁶⁸

At the 2016 Hajj, The Indian Medical Mission provided health care to about 400 000 pilgrim patients from August to October, 2016, through a team of 144 doctors, including 50 specialists, 146 paramedics, and 74 ancillary staff.⁷⁵ They coordinated a tiered health-care network, including primary-care static clinics, tent clinics, and mobile medical task forces, secondary-care hospitals, and referral and evacuation capabilities at Mecca, Medina, and Jeddah. Secondary-care referral hospitals catered for critical care, internal medicine, general surgery, orthopaedics, gynaecology, paediatrics, psychiatry, dermatology, isolation, lab medicine, and radiology. Infectious diseases constituted 53% of outpatient diagnoses, with upper and lower respiratory infections, gastroenteritis, and diabetes-related severe infections, particularly cellulitis and pneumonia the most common. Urinary tract infections were common in female pilgrims.⁷⁵

Nearly all pilgrims develop a respiratory tract infection during the Hajj, known as the pilgrims' cough.¹⁰ Overcrowding during the Hajj increases the risk of transmission of respiratory pathogens, such as Middle East respiratory syndrome coronavirus (MERS-CoV), rhinovirus, respiratory syncytial virus, influenza A H1N1, influenza B, parainfluenza virus, adenovirus, metapneumovirus, enterovirus, multidrug-resistant tuberculosis, and *Streptococcus pneumoniae*. Ebola, MERS-CoV, Alkhumra viral haemorrhagic fever, and Rift Valley fever have high outbreak potential during Hajj.^{10,76,77} Although the threat of coronaviruses (MERS-CoV and severe acute respiratory syndrome-related coronavirus) with epidemic potential remains,^{77–81} no cases of MERS-CoV have yet been identified in pilgrims during Hajj or upon return to their home countries.⁷⁹ Other coronaviruses identified at the Hajj include alphacoronavirus and betacoronavirus, of which the 229E strain is most common cause of upper respiratory tract illnesses.⁸² A systematic review of 31 studies on the prevalence of respiratory viruses in Hajj pilgrims⁷⁶ showed influenza, rhinovirus, and

parainfluenza continue to be the most common viral infections among pilgrims. At the 2016 Hajj, a study⁸³ of 266 pilgrims admitted to hospitals with community acquired pneumonia showed that 96 (36%) cases had diabetes, 26 (10%) were smokers, and 108 (45%) cases required intensive care. 48 (18%) cases had invasive *S pneumoniae* (pneumococcal) infection.

Every year the Saudi Arabian Ministry of Health issues updates on travel immunisation recommendations for pilgrims.¹⁰ They are classified as mandatory (required) and voluntary (recommended) before performing Hajj and Umrah. The three mandatory vaccines are the quadrivalent meningococcal vaccine for all pilgrims and the Yellow fever and Polio vaccines for pilgrims coming from countries with active polio transmission.^{10,68} Recommended vaccines include influenza vaccine and pneumococcal vaccine.^{84,85} Since the inclusion of the quadrivalent meningococcal vaccine in 2001,⁸⁵ no major meningococcal meningitis outbreaks related to hajj have been identified.^{85–87} However, concern that new serogroups of *N meningitidis* (eg, B and X), which are not covered in the current quadrivalent vaccine targeting serogroups A, C, W-135, and Y, could be a cause of future epidemics is increasing.^{88,89} Owing to the high incidence of pertussis seen among Hajj pilgrims in 2003,⁹⁰ *Bordetella pertussis* is considered a risk in pilgrims, especially those who have not completed their immunisation schedule.⁹¹

Tuberculosis is the commonest cause of death from an infectious disease worldwide.³⁷ A large percentage of Hajj pilgrims come from high tuberculosis-endemic countries. The burden of undiagnosed active pulmonary tuberculosis in pilgrims attending the 2015 Hajj from five high tuberculosis-endemic countries was evaluated by a study randomly screening 1164 pilgrims,³⁶ of which 15 had previously undiagnosed active pulmonary tuberculosis. With millions of pilgrims visiting Saudi Arabia from high tuberculosis endemic areas, cases of undiagnosed active pulmonary tuberculosis will continue to pose a risk to other pilgrims. Further studies are required to define the scale of the tuberculosis during the Hajj and to develop proactive screening, treatment, and prevention guidelines.⁹²

Several studies also done on enteric pathogens during the Hajj show the emergence of antibiotic-resistant bacteria (appendix).^{33,34,93} To prevent emergence of and spread of antibiotic-resistant bacteria, antibiotic prescription and consumption by pilgrims at mass gathering events should be rationalised and regulated. Antibiotic stewardship and good prescribing practices should be promoted amongst health-care providers.

Non-communicable diseases at the Hajj

Non-communicable diseases constitute a large burden on health services at the Hajj.^{10,68,94} They include diabetes, respiratory failure, myocardial infarction, cardiac failure, renal failure, chronic obstructive airways disease, prostate hypertrophy and urine retention, thyroid disorders, strokes, neuropsychiatric disorders, heat-related disorders,

traumatic injuries, ear, nose, and throat disorders, and eye ailments. The Indian Medical Mission studied 495 Indian pilgrims admitted for intensive care management during the 2016 Hajj and found that 262 (53%) had respiratory tract infections (53%) and 199 (24%) had traumatic injuries.⁶⁸ Risk factors associated with high morbidity were old age and pre-existing comorbidities. A substantial number of pilgrims participating in the Hajj are elderly with pre-existing chronic medical conditions.^{10,75,95} These pilgrims might be unable to cope with the arduous rituals condensed into a 5-day period and thus exacerbation of existing non-communicable diseases occurs.⁹⁵

Music concerts

In contrast to mass gathering religious events, sport and music concerts⁹⁶ attract younger individuals of 15–25 years of age. Excessive alcohol consumption and recreational drug use increases the risk of intoxication and injury, extreme behaviours, such as fire jumping (jumping and dancing through flames),⁹⁷ sexual activity resulting in transmission of sexually transmitted disease and sexual assault. Additionally, loud noise at music festivals can lead to deafness, hence legislation is needed to keep to certain noise thresholds.⁹⁶

Mass casualty incidents

At mass gathering events the threat of mass casualty incidents from crush injuries due to stampedes, fires, accidents (eg, airplane crashes, motor vehicles, boat collisions, crane collapse), structural failures (eg, building or bridges collapses, terrorist attacks, and toxic exposures) is ever present, and their occurrences are unpredictable. Several mass casualty incidents have occurred between 2015 and 2018 (table; appendix).

Mass casualty incidents at the 2015 Hajj

For example, during the 2015 Hajj pilgrimage, two major disasters occurred, resulting in deaths of pilgrims (table). The first occurred on Sept 11, 2015, in which a crane being used for construction to expand the area around the Grand Mosque (Masjid al-Haram) in Mecca toppled over, killing 107 people and injuring 394.³¹ The victims were from 12 countries. The second, on Sept 24, 2015, was a major stampede that occurred in Mina at the intersection leading up to the Jamarat Bridge. This incident resulted in crush injuries and suffocation, with 769 pilgrim deaths and 934 injured.³²

Reducing risk of mass casualty incidents

Owing to the sudden and unexpected nature of mass casualty incidents, they pose major challenges to health services. Preparations for mass casualty incidents are mandated by the WHO and followed by the organising authorities. When these incidences occur, local investigations and reviews are done to assess the underlying factors leading to the mass casualty incident, assess the effectiveness of the response, and identify lessons for

inclusion in future mass gathering planning.^{93,98–102} Training and simulation exercises for health-care workers in management of mass casualties and injuries should be done to assess preparedness and identify areas for improvement.

A 30-year literature review¹⁰⁰ of 290 mass casualty events at mass gatherings (1982–2012) showed that the most frequent mechanism of injury involved the movement of people under crowded conditions (162 [56%] of 290). Organisers of the Kumbh Mela and Hajj have used experiences of their mass casualty incidents to identify improvements to reduce risk at future events (appendix).

The Saudi Arabian Government has also put in place measure to reduce morbidity and mortality from heat-related disorders during the Hajj, as has the Japanese Government for the upcoming Olympics (appendix).

Reducing risk of spread of infectious diseases with epidemic potential

Global infectious threats to global health security are listed in panel 4. Media and WHO attention on Zika virus transmission at the Rio de Janeiro 2016 Summer Olympics and the 2015 Ebola virus outbreak in West Africa diverted the attention of global public health authorities from other lethal infectious diseases with epidemic potential.¹⁰³ For the Hajj and other mass gatherings appropriate travel advice on hygiene measures,^{104–107} wearing of face masks, and recommendations for

Panel 4: Current priority infectious diseases concerns which threaten global health security

- Tuberculosis
- Invasive meningococcal disease
- Invasive pneumococcal disease
- Drug-resistant bacterial, viral, and protozoal infections
- Cholera
- Typhoid
- Diphtheria
- Pertussis (whooping cough)
- Pandemic influenza
- Middle East respiratory syndrome coronavirus*
- Severe acute coronavirus*
- Measles
- Yellow fever
- Other viral haemorrhagic fevers (eg, Marburg virus*, Ebola virus*, Lassa fever*, Crimean-Congo haemorrhagic fever*, Rift Valley fever*, West Nile fever, and dengue)
- Polio (wild-type polio virus)
- Zika*
- Nipah and henipaviral diseases*
- Chikungunya*
- Sexually transmitted diseases
- Malaria
- HIV

*WHO Blueprint priority disease.

Panel 5: Needs and opportunities for cross-continental multidisciplinary research and training

- Development of a stronger evidence base for public health planning and health services for mass gatherings—coordination and collation of experiences of the organisers and hosts of the recurrent annual mass gathering events on a range of communicable and non-communicable diseases can provide ideal platforms to take the formal discipline of mass gathering medicine forward, do appropriate research to obtain a strong evidence base, and update mass gathering-specific and individual guidelines
- High quality studies that are appropriately designed and adequately powered to provide data that stands up to rigorous scientific review and can move the public health and health promotion agendas forward
- Determination of the causes of mass casualty incidences, including stampedes, crush injuries, and fires, streamlining crowd flow, management of crowd behaviour and pilgrim psychology, and implementation of measures for reducing risk
- Determination of the underlying factors of thermal disorders, pathophysiological studies, and determination of the effectiveness of measures for reducing risk
- Surveillance of diseases with epidemic potential, determination of prevalence, prevention of transmission, management of the disease and patients, prevention (vaccines, chemoprophylaxis, or infection control), and cohort follow-up studies
- Surveillance of antibiotic-resistant bacteria, determination of prevalence, prevention and monitoring of transmission, management of the disease and patients, monitoring of globalisation, and long-term cohort follow-up studies (before travel, during mass gathering event, and after mass gathering event).
- Defining the scale of the problem of non-communicable diseases and comorbidities and their effects on pilgrim health and reduction of the risk of increased morbidity, hospitalisation, and mortality.
- Advances in molecular methods, genotyping, and phenotyping for analysis of health risks and underlying genetic and other risk factors using large pilgrim cohorts
- Real-time interoperable surveillance and reporting systems for active surveillance of communicable and non-communicable diseases during mass gatherings
- Big data collection, repository, sharing, and analyses
- Creation of a mass gathering medicine specialist society or proactive global network to enable frequent dialogue and enhance international multidisciplinary surveillance, research, and training collaborations

mandatory and optional vaccines for prevention of infections are issued by local public health authorities and WHO. Occasionally authorities in countries of origin face hurdles in the implementation of these measures^{87,108} or issues regarding reduced immunogenicity of vaccines owing to interactions between vaccines.¹⁰⁹ Although no global outbreaks of meningococcal disease have occurred after the Hajj for decades, a high level of awareness of the possibility of outbreaks at all mass gatherings remains.^{87,110–112} Increasingly, attention is being focused on vaccine-preventable diseases, such as cholera, polio, measles, and pertussis, which are increasing in the eastern Mediterranean owing to conflict and large refugee populations with poor access to preventive public health services.¹¹³ The highly lethal MERS-CoV causes increasing concern, as it continues to circulate in Saudi Arabia^{78,79} and remains in the top ten of the WHO Research and Development Blueprint list of infectious diseases likely to cause major epidemics (appendix).¹¹²

Cross-continental collaborations on mass gathering medicine

More country-specific religious mass gathering events exist that attract smaller numbers of pilgrims from neighbouring countries or overseas. Several religious mass gatherings occur on a yearly basis in Iraq, drawing millions of pilgrims from across the country. The Arbaeen is one of the largest, during which pilgrims from Iraqi provinces visit the holy shrine in Karbala, and

poses major public health challenges.¹¹⁴ In West Africa, each year up to 5 million Muslim pilgrims from the Mouride community in Senegal, and from neighbouring countries, assemble in the holy city of Touba in Senegal for the Grand Magal religious pilgrimage,¹¹⁵ the largest religious mass gathering in West Africa. This pilgrimage attracts individuals from outside Africa and has the potential for globalisation of local endemic infectious diseases.¹¹⁵

Research on communicable diseases and non-communicable diseases, including heat-related disorders and disasters, with a more collaborative approach between local and international researchers and organisers of mass gathering events is required. The creation of the Africa Centres for Diseases Control (Africa CDC) on Jan 31, 2017, in Addis Ababa by the African Union, with five regional CDCs in Gabon, Egypt, Nigeria, Kenya, and Zambia,¹¹⁶ creates major opportunities for improving coordination and public health capacity-building initiatives in partnership with organisers of sporting and religious mass gathering events. For example, the majority of the livestock for ritual sacrifices during the Hajj are exported from Africa to the Middle East—the One Human-Environmental-Animal Health approach^{101,117,118} should be adopted in partnership with Africa CDC. This initiative should aim to define the risk and threats to global health security and help reduce the risk of outbreaks and spread of zoonotic infections, such as Rift Valley fever, MERS-CoV, Ebola, and other viral haemorrhagic fevers, across

For the Africa Centers for Disease Control see <http://www.africacdc.org/>

both humans and animals. This risk was illustrated dramatically by the Rift Valley fever outbreak in Jizan, Saudi Arabia, in 2000¹¹⁷ and the subsequent ban on East African livestock imports for several years.

Mass gathering events provide unique opportunities for cross-continental multidisciplinary collaborations on public health and basic science research, which will allow for the development of a strong evidence base for public health planning and health services at mass gatherings (panel 5). Although the formalisation of mass gatherings medicine has led to an increase in research studies into the specific health issues affecting pilgrims at the Hajj, they have not been forthcoming for the Kumbh Mela and other mass gatherings. Research output from mass gathering events is focused on small studies of pilgrims from individual countries and the data are not generalisable and no outputs have changed global policy. A need remains for more coordinated action by a global coalition of interested partners to share experiences from various mass gathering events, gather and translate appropriate evidence base into public health policy, and push for the best health promotion and educational policies. The creation of a mass gathering medicine specialist society or formal network, with a dedicated journal, might generate more frequent dialogue and enhance international collaborations on mass gathering medicine. A need also remains for high quality studies that are appropriately designed and adequately powered using participants from several geographical regions to provide data that stand up to rigorous scientific review. Advances in technology and closer monitoring of pilgrims at the Hajj provide an opportunity for large cohort studies of attendees of mass gathering events. These studies could focus on infectious diseases priorities, including neglected tropical diseases,¹¹⁹ non-communicable diseases, mental health, and heat-related disorders (panels 4 and 5). The widespread availability of next-generation sequencing, genotyping and phenotyping, and other molecular methods also provides an opportunity for analyses of health risks among large population cohorts and for appropriate research to obtain an evidence base for the production of WHO-approved guidelines, which will be useful for countries that host mass gathering events.

Structured, real-time interoperable surveillance and reporting systems are required for active surveillance of communicable and non-communicable diseases during mass gatherings.¹²⁰ Given the continuing threat of new emerging and re-emerging infectious diseases with epidemic potential, regularly recurring mass gathering events, can act as important global sentinel surveillance platforms.¹²⁰ Additionally, diseases targeted by WHO for elimination, such as polio, are still endemic in some countries from where individuals attending mass gathering events originate, offering opportunities for research and evaluation of public health portfolios.¹²¹ Increased investments in the field of mass gathering

medicine are required to obtain an accurate evidence base for the development of accurate prevention, management, and control guidelines and optimal public health services to protect the health of attendees of mass gatherings and of host country populations.

Contributors

ZAM and AZ ideated the review. ZAM and AZ developed the first draft outline. All authors contributed equally to the writing and finalisation of the manuscript.

Declaration of interests

ZAM, RS, OD, EIA, and AZ were members of the group that formalised mass gathering medicine as a discipline. ZAM and AZ were authors for and coordinated the 2014 *Lancet* Series on mass gatherings. ZAM was founding director of the Global Center for Mass Gatherings Medicine and the WHO Collaborating Center for Mass Gatherings, Saudi Arabian Ministry of Health. In the past 3 years, RS has received support to attend advisory boards or present paid lectures by GlaxoSmithKline, Mériex (Fondation), PaxVax and Emergent BioSolutions, Pfizer, Sanofi Pasteur, Takeda, and Valneva, and he has been principal investigator or adviser to Aries, Clasado and Host Therabiomics, and Dr Falk Pharma. PW and AS declare no conflicts of interest.

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