TITLE:

Mass Gatherings Medicine - Public Health Issues Arising from Mass Gathering Religious and Sporting Events

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ABSTRACT / SUMMARY (310 words)

Mass Gathering (MG) events, spontaneous or planned, are associated with major public health challenges including infectious diseases transmission, stampedes, fires, heat disorders, mental health, and exacerbation of non-communicable diseases. Mass Gathering Medicine (MGM) as a specialty emanated from discussions for the 2009 Hajj when the 2009 HIN1 influenza pandemic was a major threat to global health security. The first International Conference on MGM was held in Jeddah, Saudi Arabia in October, 2010 where The Lancet Infectious Diseases Series on Mass Gatherings was the launch point. The new MGM discipline was further highlighted at the World Health Assembly of Ministers of Health in Geneva in May 2014, where The Lancet 2014 series on MGM was launched. The Lancet 2014 MGM series covered the planning and surveillance systems used to monitor public health risks, public health threats, and experiences of healthcare providers from MG sporting and religious events: the London 2012 Olympic and Paralympic Games; the 2012 European Football Championship finals (Euro 2012), and the Hajj pilgrimages 2012 and 2013. This follow-up review highlights the main public health issues arising from planned religious, sporting, scout, cultural and musical MG events held between 2013 and 2018: The Kumbh Mela 2013 and 2016 pilgrimages in India; the Festival of Pacific Arts; United Nations Small Island Developing States conference and the Micronesia Games in the Pacific Island Countries and Territories (PICTS); The Rio de Janeiro Olympic games 2016; Russia FIFA World Cup 2018; The World Scout Jamboree 2015 in Japan; the annual Hajj pilgrimages 2015, 2016 and 2017 in Saudi Arabia. We highlight recent public health and research data on transmission of infectious diseases and antibiotic resistant bacteria, mass casualty incidents, non-communicable diseases including heat disorders. Priorities for further investments and opportunities for conduct of research into prevention, surveillance, and management of communicable and non-communicable diseases, thermal disorders, crowd behaviour and mass casualty incidents at MG events are discussed.

SEARCH STRATEGY

We searched PubMed, EMbase, Cochrane Library and Google Scholar for English language papers that were published from January 1st 2012 to January 1st 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 Centres for Disease Control (ECDC) and the US Centres for Disease Control and Prevention, Saudi Arabian Ministry of Health and Ministry of Hajj websites, and Public Health England (PHE). We reviewed studies cited in articles identified in our searches and selected those that we identified as relevant.

AUTHOR DECLARATIONS

All authors have an interest in Mass Gatherings and Mass Gatherings Medicine. All authors declare no other conflicts of interest.

BACKGROUND

A Mass Gathering (MG) is defined by the World Health Organization (WHO) as a planned or spontaneous event which gathers substantial numbers of attendees who may strain the health planning and response capacities of the host community, city or country.[1] MGs can impose important public health challenges related to the health of attendees and the host country population and health services.[2] The historical evolution of Mass Gatherings Health as a priority global agenda is depicted in **Table 1**. The concept of Mass Gathering Medicine as a specialty emanated from discourse on the 2009 Hajj which was held during the 2009 HIN1 influenza pandemic.[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 the launch point.[4] This led to a coalition of experts from virtual WHO MG collaborating centres and global academic and public health faculty[5] to guide development of, and update, optimal public health and medical prevention and treatment guidelines at MG events.[6]

Mass Gatherings Medicine' (MGM) 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 MGM 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 healthcare providers from three MG sporting and religious events: the London 2012 Olympic and Paralympic Games[8]; the 2012 European Football Championship finals (Euro 2012)[9], and the Hajj pilgrimages 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, (**Table 2**) and experiences of healthcare providers.

MASS GATHERINGS EVENTS 2013-2018

Since the launch of the Lancet series in 2014, various public health threats have continued to pose 'pre-event planning' and 'during event' public health challenges at various MG events. This follow-up review highlights the main public health issues arising from planned religious, sporting, scout, cultural and musical MG events held between 2013 and 2018: The Kumbh Mela 2013 and 2016 pilgrimages in India; the Festival of Pacific Arts; United Nations Small Island Developing States conference and the Micronesia Games in the Pacific Island Countries and Territories (PICTS); The Rio de Janeiro Olympic games 2016; Russia FIFA World Cup 2018; The World Scout Jamboree 2015 in Japan and the annual Hajj pilgrimages 2015, 2016 and 2017 in Saudi Arabia. We highlight recent public health and research data on transmission of infectious diseases, emergence of antibiotic

resistant bacteria, mass casualty incidents from stampedes and terrorist attacks, and non-communicable diseases including heat disorders. Priorities for further investments and opportunities for conduct of research into prevention, surveillance, and management of communicable and non-communicable diseases, thermal disorders, mass casualty incidents are discussed.

THE KUMBH MELA

The Kumbh Mela is a hindu religious pilgrimage festival which is the largest MG event in the world attracting over 120 million pilgrims.[11-16] It is held four times over a period of 12 years and lasts up to two months in duration. It attracts pilgrims from across the world and is held in three yearly rotations along the banks of four 'holy' rivers: The Ganga or Ganges River (at Haridwar district), Godavari River (at Nasik district), Kshipra River (at Ujjain district) and Sangam River (at Prayag district, Allahabad) at a confluence of Ganga, Yamuna and Saraswati. Specific dates for the ceremonies are worked out through combinations of zodiac and the positions of the sun, moon, and Jupiter in the lunar calendar.[17,18] These three yearly ceremonies culminate in the buildup to the 'Purna' (full) Kumbh ceremony typically held every 12 years attracting up to 120 million pilgrims. A substantial increase in the attendees is often seen on certain auspicious days to take holy dips in the river.[21] This poses major challenges in crowd control and flow of pilgrims. The public health challenges are generic to that of the Hajj.[10] 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 and key WHO recommended considerations related to setting up and implementing health alert, response and operational plans for mass gatherings are followed[1,2] (**Table 3**). The Indian Government and local authorities plan well ahead of each Kumbh Mela event and has in place established plans for setting up the required physical and public health infrastructures to look after the welfare of millions of pilgrims. Temporary 'cities' along the river delta are setup which include tents for pilgrims, provision of water pipelines, clean water supply, toilets, sanitation and sewage disposal facilities, vector control and surveillance teams, security services and administrative assistance for pilgrims. [20-22] A range of healthcare facilities are put in place and hospitals are prepared to receive pilgrims requiring inpatient treatment and intensive care.[21] These infrastructures are-built for every Kumbh Mela festival and thus the name temporary 'popup city' is attributed to this. Construction of internal roads and multiple pontoon bridges are designed to streamline and facilitate pilgrim crowd movement and flow.[22] Government state officials and Central Pollution Control Board work closely together to increase the capacity of sewage treatment plants and the flow rate of rivers.

The 2013 Kumbh Mela included supply of 90,000 kl/day of portable water for drinking and cooking, with 550 km of water pipelines for distribution through 20,000 taps. Approximately 45,000 toilets were provided although health promotion messaging was limited.[21] Like other MGs, random inspection and vaccinations were carried out for immunocompromised individuals.[21]

Infectious diseases transmission at the Kumbh Mela

Compared to other MG events, the Kumbh Mela uniquely involves frequent and prolonged bathing by pilgrims in the holy river, a ritual performed to 'escape the cycle of reincarnations and acquire immortality'.[17,18] The massive crowds living together in crowded conditions inevitably results in contamination of river water with faeces, urine, saliva and sputa and results in transmission of waterborne and respiratory tract infections.[12,14,20,21] The 1817–24 Asia cholera pandemic was associated with the Kumbh Mela.[23] During the 2013 and 2016 Kumbh Mela ceremonies, despite availability of toilets, these pilgrims engaged in open defecation and urination.[21] This, along with overflowing toilets and garbage leachates drained into the river results in an approximately 130-fold increase in river bacterial load, creating conditions for transmission of water borne pathogens through drinking of 'holy' river water, a common practice during the Kumbh Mela.[12,24-29] At the 2013 Kumbh Mela, a study followed up 30,000 pilgrims in four sector hospitals and found a 5% incidence of diarrhoeal diseases over a 23-day period.[15,16,20] A rise in non-bloody diarrhoea cases was seen just 2 days after the main bathing day that was on 29 January 2013. Also observed in the study was a peak in upper respiratory tract infections which coincided with the peak in non-bloody diarrhoeal disease. The use of cow dung or firewood by pilgrims to light fires resulted in over 23% seeking cough medicine, and smoke from choolahs using wood or coal was the commonest cause of respiratory illnesses among 15,000 patients.[13] It was observed that the shaving ritual has the risk of transmission of blood-borne diseases, although the lack of information on how widespread the practice is and the secrecy surrounding the practice, prevents evaluation of the problem.

Emergence and transmission of antibiotic resistant bacteria at the Kumbh Mela

Recently concerns regarding the spread of antibiotic-resistant bacteria and mass-gathering religious events arise from the presence of ESBL *E.coli* in municipal sewer systems and waste water in Hyderabad, India.[26] The rivers of India are known to be polluted due to inadequately treated household and industrial effluents.[26-27,29] A 20-fold increase in blaNDM-1 gene carrying bacteria during the pilgrimage on the bank of river Ganges [27] was observed during the 2015 Kumbh Mela. A novel drug resistant bacterial species, *Corynebacterium godavarianum,* has been isolated from the bathing site of the Godavari river.[25] The growing global concerns relating to travel-related globalisation of multi-resistant enteric bacteria, such as *Escherichia coli* ESBL[28] led to an expert

panel to conclude that antibiotics should be restricted to those in whom acute travellers' diarrhoea is incapacitating.[30]

Stampedes at the Kumbh Mela

Close surveillance and constant evaluation of crowd flow has minimised the risk of crush injuries, stampedes and other mass casualty incidents such as fires. The site preparation and negotiations with the various 'akahras' (sects) to pre-determine the order of ritual baths has resulted in reducing the number of death due to stampedes from ~500 people in 1954 to 36 in 2013.[21] Two stampede events occurred recently. The first during the 2013 Kumbh Mela where a stampede at a nearby railway station resulted in deaths of 37 Pilgrims.[22] The second occurred on banks of Godavari during the 2015 Kumbh Mela where 27 pilgrims died.[21]

THE FESTIVAL OF PACIFIC ARTS AND THE MICRONESIA GAMES

The Festival of Pacific Arts and the Micronesia games are a feature of Pacific island countries and territories (PICTS).[31-33] Though the events and the PICTS are small in population size the health security risks remain the same and in relation to population size and the influx of people can be proportionally greater than similar events in larger countries. Being small and with several event hosting countries having a population under 200,000, such as Yap State (population 11,000) in the Federated States of Micronesia (FSM) who hosted the 9th Micronesia games in July 2018, means that potential impacts of MGs on the small and fragile health infrastructure of these countries can be significant. Three enhanced surveillance activities for mass-gathering events in PICTS occurred during national or regional disease outbreaks which had the potential to severely impact the MGs placing greater strain on health services as well as causing significant tourism related economic and reputational loss.

1). The 8th Micronesian Games took place in Pohnpei State, FSM in July 2014.[33] Pohnpei is a Micronesian small island state of around 36,000 people in the western Pacific slightly north of the equator. The games attracted approximately 1700 athletes and officials from the Micronesian countries and territories of the Commonwealth of the Northern Mariana Islands; the four FSM states of Chuuk, Kosrae, Pohnpei and Yap; Guam; Kiribati; Nauru; Palau and the Republic of the Marshall Islands. In June 2014 six weeks before the opening of the games, Pohnpei reported its first of an eventual 251 measles cases in an outbreak that spanned the games and continued for a further 3 months.[34]

2). The 3rd United Nations Conference on Small Island Developing States (SIDS) was held in Apia, Samoa in September.[34] Attracting more than 3,000 delegates from 115 countries this was the largest ever hosted by Samoa, a Polynesian island nation in the south Pacific with a population of around 187, 000. In late July 2014 Samoa experienced the beginning of an extensive chikungunya

virus disease (CHIKV) outbreak that by late August, two weeks before the SIDS conference, resulted in 308 suspected and confirmed cases,[35] and that four months later had over 4,000 cases.[36]

3). The 12th Festival of Pacific Arts (FESTPAC) was hosted by Guam in 2016.[37] Guam with a population of around 163,000 is a Micronesian island nation in the western Pacific and an unincorporated territory of the United States. This was a very large event attracting more than 2,500 artists and performers from 27 countries and territories across the Pacific, including very small island communities such as the Pitcairn islands, which with less than 50 residents, would have been devastated if a novel disease was introduced. FESTPAC occurred during the Zika, Dengue Chikungunya and Measles outbreaks which affected several FESTPAC participating countries.[33,35,36,38] In the face of these, the enhanced surveillance for these MGs was essential for health security assurance.[34,39] In all these MGs the combination of a large influx of people and a high degree of social mixing in the presence of highly infectious pathogens (measles, in Pohnpei), emerging non-vaccine preventable diseases (CHIKV, in Samoa) and diseases with non-curable highly emotive impacts (Zika birth defects, in Guam) could have had significant consequences to these tourism dependent economies beyond the considerable health burden and strain on vulnerable health systems. To counter these threats prompt response actions were an inherent part of the MG enhanced surveillance plans, aiming to ensure that none of these high-profile events were impacted by health security concerns.

Whilst no systematic active global surveillance systems are in place for MGs, all three MG events employed, enhanced syndromic surveillance that built on the existing pan-Pacific Word Health Organization Western-Pacific (Suva, Fiji sub-regional office) led weekly syndromic surveillance.[40] This ensured the hosting countries had few 'surprises' as to what the enhanced surveillance involved as it essentially comprised three activities: a) daily rather than weekly data collection and reporting; b) expanding from 4 to up to 12 syndromes that explicitly included the outbreak diseases occurring in or around all three hosting countries at the time of their MGs; and c) expanding the number of sentinel sites in the communities impacted by the MG. However, while familiar with the process of implementing the surveillance, the short period of intense activity that characterizes MG enhanced surveillance (encompassing daily data collection, collation, analysis, interpretation and dissemination) is a significant burden on what are already stretched local public health resources and is not to be underestimated. To alleviate the strain additional public health support was gained both from within the hosting country and from external partners. The principle external support was provided by the Pacific Community (SPC), the pan-Pacific technical support organization; and also in the case of FESTPAC, from the Pacific Island Health Officers Association (PIHOA) that supports the six United States Affiliated Pacific Islands.[41]

All three mass-gathering enhanced surveillance activities had similar aims: providing early warning surveillance for rapidly detecting and responding to disease outbreaks; disseminating health security information to neighboring PICTS; and strengthening disease surveillance in the hosting country. The first two objectives were met with none of the outbreaks ongoing in the hosting or neighboring countries impacting the MGs. Similarly, the pre-existing PacNET Pacific regional early-warning surveillance email service hosted by the Pacific Public Health Surveillance Network (PPHSN) that is commonly used by PICTS to share surveillance information served as a very effective delivery platform for information dissemination.[41] The third activity, sustainably strengthening in-country public health surveillance, is however harder to objectively and directly assess. Though can perhaps be measured indirectly from the value of regional organizations and the network of relationships with PICTS.

The host countries were able to implement enhanced surveillance because of two critically important factors. *Firstly*, having the MG enhanced surveillance build on the existing surveillance system in the hosting country and that is adopted across PICTS and supported by the WHO and *secondly*, in all three occasions the hosting country partnered with the Pacific Community who has extensive experience in implementing MG surveillance and has established working relationships with the hosting countries and their public health departments.[40,41] It is through this lens that these MG enhanced surveillance activities in three small PICTS demonstrated the value of a strong foundation in existing disease surveillance and the value of regional partnerships. All three surveillance activities built on an existing surveillance platform; and greatly benefited from close ties with regional international non-governmental organizations. These two aspects made the essential difference in the hosting countries ability to implement a comprehensive and intensive enhanced surveillance. However, while raising awareness of the value of early-warning disease surveillance, actual longer-term benefits of strengthened sustainable surveillance improvements are harder to realize. MGs are characterized by a relatively short period of intense activity. In all three of these MGs the local public health department borrowed personnel from other departments and benefited from external partner resources; all of whom returned to their day jobs/left island once the enhanced surveillance finished; effectively leaving the much smaller (1 or 2 person) surveillance teams to carry on as before, thereby losing some of the experience gained from the MG.

The MG enhanced surveillance was successful[40,41] in all three occasions and demonstrated that even small nations can (with the right support) provide competent health security in the face of significant health risks. These events all had several things in common. They were large events proportional to the size of the countries that generated an influx of people from countries with endemic outbreak prone infectious diseases; all occurred during significant on-island or

neighboring island infectious disease outbreaks; implementing enhanced MG surveillance was a considerable undertaking with planning commencing up to a year before the events and all three countries required assistance to implement the enhanced surveillance. These events proved the value of the surveillance in providing essential health security assurance to event organizers, participants, local and wider regional communities as well as demonstrating the ability that small island nations can meet International Health Regulations requirements and implement enhanced surveillance for MGs events.

THE 2016 RIO DE JANIERO OLYMPIC GAMES

There were various public health concerns raised before the Rio Olympics in August 2016.[42-45] In February, 2016 the World Health Organization declared the Zika virus a public health emergency of international concern in light of the Zika outbreak in Brazil and its association with birth defects.[44] There was global pressure for the games should be either postponed or moved to another country. The concern was that 500,000 foreign tourists would attend the event and thus it was unethical to expose them to the risk of acquiring Zika.[46]

The WHO Emergency Committee on Zika response based on technical consultation and expert input was that there was no public health justification for postponing or cancelling the Games [43,44,45,47] stating that 'individual risks in areas of transmission are the same whether or not a mass gathering is conducted, and can be minimized by good public health measures".[44] Since Brazil is a dengue endemic country, there was concern about the risk of dengue to non-immune foreign visitors coming to attend the 2016 summer Olympic games.[48] This was based on the experience from a pilgrimage in Senegal[49] and from GeoSentinel data. GeoSentinel is a global network of travel medicine.[50,51] providers focussing on sentinel surveillance, generating also evidence-based assessment of infectious disease risks for future mass gatherings events.

As with the London Olympics 2012[18] WHO provided technical support to the Ministry of Health, Brazil and International Olympic Committee to ensure public health safety during the games for various public health issues. This included improving the quality of recreational water quality and preventing the spread of Zika virus. Apart from the global media frenzy over the Zika virus, there were no significant events of international public health concern reported since the end of the Rio Games. There were no reports of confirmed cases of Zika virus among people who attended the Games, both during the games and since return to their home countries.[44,52,53] This illustrated that having strong risk communication systems and a firm evidence-based risk management strategy is key to resisting unfounded media and political pressure as well as the furore created by the open letter.

Before the Rio Olympics, another concern was related to water sports and athletes being exposed to polluted waters.[54] However, a study performed during pre-Olympic tests in 2015 showed no increased rates of diarrhoea among those exposed as compared to controls.[54] When travellers to the FIFA world cup 2014 were compared to other travellers to Brazil during the same period, the majority in both groups obtained insect bites and sunburns as environmental risk factors, and every third traveller suffered from diarrhoea.[52,54] Males tended to have more sexual contacts outside of a relationship than travellers in a control group and also had more alcohol intake.[48]

RUSSIA FIFA WORLD CUP 2018

The FIFA World Cup 2018 was hosted by Russia from 14 June to 15 July 2018.[55] The event was attended by three 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.[56] Pre-event data from WHO's Regional Office for Europe,[56] showed the Russian Federation reported 454 isolates from blood and cerebrospinal fluid samples from urban tertiary care hospitals across the Russian Federation. Carbapenem resistance was 74% in *Acinetobacter spp*, 49% in *Pseudomonas aeruginosa* and 12% in *Klebsiella pneumoniae*. 23% of *Staphylococcus aureus* isolates were MRSA and 91% of *Klebsiella pneumoniae* isolates were resistance to third-generation cephalosporins. Whilst there were no reported major public health incidences, the World Cup 2018 created heightened awareness of the threat of the transmission and globalization of antibiotic resistant bacteria. No cross-sectional or longitudinal cohort studies from the event have been published yet.

WORLD SCOUT JAMBOREE 2015

The 23rd World Scout Jamboree (WSJ) was hosted by Japan from 28 July to 8 August 2015 and was attended by 33,000 scouts aged up to 17 years from 162 countries.[57] The WSJ is an international scout camp of the WHO Scout Movement. It takes place every four years with site of the WSJ rotating across continents. National Scouting Organisations apply to arrange and host the jamboree. The daily schedule included arduous activities such as climbing, chopping and knife handling, preparing own meals on gas stoves. Apart from risk of infectious diseases transmission, injuries, and burns, it induces a range psychological disorders from homesickness, behavioural and neuropsychological disorders.[58]

There were no major infectious diseases outbreaks reported during the jamboree. However, within nine days of the end of the event, six cases of laboratory-confirmed invasive meningococcal disease (IMD) caused by *Neisseria meningitides* capsular serogroup W meningococcal disease (IMD)

occurred among scouts and their close contacts in Scotland and Sweden.[59-61] Soon after return to Scotland, three scouts and one relative were diagnosed with IMD. The four confirmed cases identified in Scotland, were all associated with one scout unit. There were two confirmed cases of IMD reported from Sweden. Molecular analysis showed the same *N. meningitides* isolates were responsible for the six cases and they belonged to the ST-11 clonal complex (cc11) 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 through a massive information campaign of the outbreak and of signs and symptoms of IMD and were offered ciprofloxacin chemoprophylaxis.[60,61] To make a decision on the need for prophylactic treatment for close contacts of returning scouts, throat and/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 1,020/1,890 of the Swedish teenagers who participated in the Jamboree. The overall positivity for *N. meningitidis* in this group was 8% (83/1,020) of which 61/83 were non-groupable.[61] Further carriage studies are required during MGs to determine the current epidemiology and association between carrier isolates and disease-causing isolates in the population and the dynamics of globalisation from MG events.

THE HAJJ ANNUAL PILGRIMAGES - 2015, 2016 and 2017

Every year there continues to be an increasing number of people coming to Saudi Arabia for Hajj and Umrah pilgrimages.[62] The total number of pilgrims for both hajj and Umrah is currently approximately 10 million pilgrims annually from over 180 countries. The hajj pilgrimages which took place in 2015, 2016 and 2017 each attracted over 2 million people from outside Saudi Arabia.[62] Several major public health challenges associated with each Hajj,[10] including transmission of infectious diseases and antibiotic resistant bacteria, exacerbation of non-communicable diseases, mental health disorders, heat-related disorders and stampedes, amongst others. Infectious diseases surveillance systems are operational during the annual Hajj, and these have evolved from the paper-based reporting tools to automated electronic systems or recording and storing large data sets and reporting from mobile units, clinics, primary health facilities and hospitals which serve pilgrims. [10] All these data are fed directly to a central command and control unit, enabling rapid synthesis and analyses of data and instituting public health interventions as necessary. These advances in real-time surveillance has improved public health security for the mass gatherings at Hajj.[63]

Infectious diseases at the Hajj

Over the past 5 years there has been growing concern of the threat to global health security posed by several emerging and re-emerging infectious diseases. In light of the Ebola outbreaks in West Africa[63] (2013-2016); the cholera outbreak in Yemen (2015-2018)[64]; Zika virus in the Americas and south-east Asia (2016-2018)[43-45]; Lassa fever Nigeria (2018)[65]; Diphtheria in Venezuela (2016-2017)[66] and in Yemen[67] (2017-2018); Yellow Fever in Latin America and Africa (2016-2018); and Nipah virus in India and South Asia (2017-18)[68], there were calls to prevent pilgrims from affected countries from travelling to Saudi Arabia for Hajj or Umrah. The Saudi government implemented restrictions only to countries affected by Ebola outbreak. For pilgrims from Yemen and other countries, intensified screening at points of entry into Saudi and close surveillance during their stay throughout the Hajj, was implemented, with no cases detected.[62]

At the 2016 Hajj, The Indian Medical Mission provided healthcare to approximately 400,000 pilgrim patients from August to October 2016 through a team of 144 doctors including 50 specialists, 146 paramedics and 74 ancillary staff.[69] They coordinated a tiered healthcare network including primary-care static-clinics, tent-clinics and mobile medical task-forces; secondary-care hospitals; 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 were the most common (53%) outpatient diagnosis with upper and lower respiratory infections, gastroenteritis and diabetes-related severe infections, particularly cellulitis and pneumonia. Urinary tract infections (UTI) were common in female pilgrims.[69]

Nearly all pilgrims develop a respiratory tract infection during hajj and have 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 (MDRTB), *Streptococcus pneumoniae*. Ebola, MERS-CoV, Alkhumra viral haemorrhagic fever, and Rift Valley Fever have high outbreak potential during Hajj.[10,70,71] Whilst the threat of coronaviruses (MERS-CoV and SARS-CoV) with epidemic potential remains[71-75] no cases of MERS-CoV have yet been identified in pilgrims during hajj or upon return to their home countries.[73] Other coronaviruses identified at the Hajj include alpha coronavirus and beta coronavirus of which 229E strain is most common cause of upper respiratory tract illnesses. [76] A systematic review of 31 studies on the prevalence of respiratory viruses in Hajj pilgrims[70] showed Influenza, rhinovirus and parainfluenza continue to be the most common virus infections among pilgrims. At the 2016 Hajj a study of 266 pilgrims admitted to hospitals with community acquired pneumonia showed that 36% of the cases had diabetes, 10% were smokers, and 45% of cases

required intensive care(ICU).[77] 18% of cases had invasive *Streptococcus pneumoniae* (pneumococcal) infection.

Every year the Saudi Arabian Ministry of Health issues updates on pre-travel immunisation recommendations for pilgrims.[10] These are classified as mandatory (required) & voluntary (recommended) prior to performing Hajj and Umra. The 3 mandatory vaccines are the quadrivalent meningococcal vaccine, Yellow fever vaccine and Polio vaccine for pilgrims coming from countries with active ongoing polio transmission.[10,62] Other recommended vaccines include influenza vaccine and pneumococcal vaccine. [78,79] Since the inclusion of the quadrivalent meningococcal vaccine in 2001 (Harrison et al, 2011), no major meningococcal meningitis outbreaks related to hajj have been identified[79],[80,81] . However, there is a rising concern that new serogroups of Neisseria meningitidis (B,X)which are not covered in the current quadrivalent vaccine would be a cause of future epidemics. [82,83] Due to the high incidence of pertussis seen among Hajj pilgrims in 2003.[84] *Bordetella pertussis* is still considered a risk in pilgrims, especially those who did not complete their immunization schedule updated. [85]

Tuberculosis (TB) is currently the commonest cause of death from an infectious disease worldwide.[86] A large percentage of Hajj pilgrims come from high TB-endemic countries. The burden of undiagnosed active pulmonary TB in pilgrims attending the 2015 Hajj from five high TB-endemic countries was evaluated by a study randomly screening 1,164 pilgrims from 5 countries.[87] 15 pilgrims had previously undiagnosed active pulmonary TB disease. With millions of pilgrims visiting Saudi Arabia from high TB endemic areas, cases of undiagnosed active pulmonary TB will continue to pose a risk to other pilgrims. Further studies are required to define the scale of the TB problem during the Hajj mass gathering and the development of proactive screening, treatment and prevention guidelines.[88]

Transmission of antibiotic resistant bacteria at the Hajj

There have been several studies on enteric pathogens during Hajj which show the emergence of antibiotic resistant bacteria.[89-91] Increased carriage rates of enteric pathogens have been noted including *Tropheryma whipplei*[92], multidrug-resistant nontyphoidal Salmonella,[93] extended-spectrum β-lactamase producing *E. coli* and *Klebsiella pneumoniae*[90], colistin-resistant *E. coli* and *K. pneumoniae* and carbapenemase-producing *E. coli*.[93] Moreover, acquisition of CTX-M genes at the Hajj was associated with the occurrence of diarrhoea and was related to the use of β-lactams.[73] A prospective cohort study of French Hajj pilgrims was conducted to determine the acquisition of enteric pathogens during the 2016 Hajj.[94] Rectal swabs were performed before leaving France and before returning from Saudi Arabia. Of 117 pilgrims studied, 13.7% experienced diarrhoea during Hajj. Of the pre-Hajj samples, 32.5% were positive for at least one pathogen compared to 50% of

post-Hajj samples. Diarrhoea associated with enteropathogenic *E. coli* (EPEC), enteroaggregative *E. coli* (EAEC), and Shiga-like toxin-producing *E. coli*, were acquired by 29.9%, 10.2%, and 6.5% pilgrims, respectively. A lower prevalence of EPEC (22.5%) in pilgrims was seen in pilgrims who washed their hands more frequently at the Hajj than usually as compared to others.[94] To prevent emergence of and spread of AMR bacteria, antibiotic prescription and consumption by pilgrims at MG events should be rationalised and regulated. Antibiotic stewardship and good prescribing practices should be promoted amongst healthcare providers.

Heat related disorders

The 2015, 2016, 2017 Hajj pilgrimages occurred during the summer season, when the temperatures in Makkah and Madina exceeded 45°C. Heat related disorders at mass gatherings events held in tropical countries are important health issues.[95-98] High temperatures can cause heat related illness ranging from minor ailments (such as sunburn, cramps, leg oedema, prickly heat, and syncope) to more serious conditions (dehydration, electrolyte imbalance, shock, heat exhaustion, heat hyperpyrexia, organ failure, convulsions, increasing intracranial pressure coma, heatstroke and mental disorders.[95-99] Many factors play a role in the outcome of heat illness in pilgrims, including old age, chronic disease, overcrowding, physical exertion, lack of acclimatization, and dehydration. Elderly people are more likely to succumb to heat illness due to decreased blood flow to the skin, poor sweat gland function, and chronic cardiac, lung and renal co-morbidities.[97,100] A cross-sectional study conducted during the 2016 Hajj looked at heat related disorders in 267 pilgrims admitted with heat stroke, heat exhaustion, hyperthermia and electrolyte imbalance.[95] The mean age of the patients was 54.0 ± 16 years. Diabetes mellitus was the most common comorbidity among these patients. The median length of the hospital stay was two hours with a maximum stay of 57 hours. 84% of patients with heatstroke were treated successfully and were discharged. 7% died and 5.7% were admitted to critical care units.

Non-Communicable Diseases at the Hajj

Non-Communicable diseases constitute a large burden on health services at the Hajj. [10,62] A large cohort study of nearly 140,000 pilgrims accessing healthcare at the 2016 Hajj by the Indian Medical Mission showed that Non-communicable diseases were important causes of morbidity and mortality in pilgrims.[100] These included diabetes, respiratory failure, myocardial infarction, cardiac failure, renal failure, chronic obstructive airways disease, prostate hypertrophy and urine retention, thyroid disorders, strokes, heat-related disorders, traumatic injuries, ENT disorders and eye ailments. The mission coordinated tertiary-care transfers with 30 Saudi-Arabian hospitals in Mecca, Medina and Jeddah where 495 patients were admitted, for intensive care management. Most common causes of admission were overwhelming respiratory tract infections (53%) and traumatic

injuries (24%). 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] These pilgrims are inadequately prepared mentally and physically to cope with the arduous rituals condensed into a five-day period and thus exacerbation of existing NCDs occurs.

Mass casualty incidents at the Hajj 2015

During the 2015 Hajj pilgrimage there were two major disasters in Makkah, Saudi Arabia, resulting in deaths of pilgrims. The first occurred on September 11, 2015, a crane being used for construction to expand the area around the Grand Mosque (Masjid al-Haram) in Makkah, accidentally toppled over, killing 111 people and injuring 394.[101] The victims were from twelve countries. The second, on 24 September 2015 was a major stampede which occurred in Mina at the intersection leading up to the Jamaraat Bridge. This resulted in crush injuries and suffocation with over 700 pilgrim deaths and 43,345 being injured[102] although the exact casualty figures remain unknown.

MUSIC CONCERTS

In contrast to MG religious events, sport and music concerts[103] attracts the younger generation of between 15-25 years of age in whom spread of sexually transmitted diseases is common. Excessive alcohol consumption, recreational drug use increases the risk of drug intoxication and injury, extreme behaviors like 'fire jumping' (jumping and dancing through the flames by way of a victory dance)[104] and more traditional risks of sexual assault. In addition, the loud noises at music festivals can lead to deafness, and hence legislation is needed to keep to certain noise thresholds. [105]

Mass casualty incidents at music festivals 2017

Route 91 Harvest Country Music Festival - Las Vegas

The October 2017 Route 91 Harvest Country Music Festival held in Las Vegas, was attended by over 22,000 people. On the final day of the festival, October 2nd, 2017, a lone 64-year-old gunman without any political, racial, or religious agenda, or history of mental illness or criminal behaviour, went on a shooting spree. He shot dead 58 people and injured another 515 by firing thousands of rounds of ammunition from the 32nd floor of a nearby hotel.[106]

Manchester Arian Grande Music concert

On 22 May 2017, a terrorist detonated an improvised shrapnel-laden homemade bomb when attendees were leaving Manchester Arena at the end of a music concert where the American singer Ariana Grande performed. Twenty-three people were killed, and 159 people were wounded, more

than half of them children.[107] Post attack several hundred attendees who suffered from psychological problems.[108]

REDUCING RISK OF MASS CASUALTY INCIDENTS

At mass gathering events the threat of Mass Casualty Incidents (MCI) at from crush injuries due to stampedes, fires, accidents (eg airplane crashes, motor vehicles, boat collisions, crane collapse), structural failures (eg building or bridges collapses: deliberate events dues to terrorist attacks, and toxic exposures) is ever present, and their occurrences are unpredictable.

Table 4 summarises a selection of unexpected mass casualty incidences at various MG events in the past 5 years. [22,101-112] Due to the sudden and unexpected nature of these events, these incidents pose major challenges to health services. Preparations for MCIs are mandated by the WHO and followed by the organising authorities. When these incidences occur, local investigations and reviews are taken forward to assess the underlying factors leading to the MCI, the effectiveness of the response and identify lessons which can be learnt for inclusion in future MG planning.[91, 109-113] Training and simulation exercises for healthcare workers in management of mass casualties and injuries should be undertaken to assess preparedness, the effectiveness of the response, but also to identify areas for improvement.

Preventing stampedes at future MG events

A 30-year literature review of 290 Mass casualty events at MGs (1982 to 2012) showed that the most frequent mechanism of injury involved the movement of people under crowded conditions (162/290: 56%).[111] Organisers of the Kumbh Mela and Hajj have used experiences of their recent mass casualty incidents to identify improvements to reduce risk at future MG events.

Preventing stampedes at Kumbh Mela

With an ever-increasing number of pilgrims attending the Kumbh Mela, the Indian government has well prepared plans for future pilgrimages.[114-116] For the current ongoing 2019 Kumbh Mela the Indian government has created multiple access for pilgrims through different routes to the river and built additional temporary bridges for smoother and streamlined flow of pilgrims. Use of modern technologies such as satellite imaging and CCTV cameras to monitor and direct flow of pilgrims are being taken forward to improve the safety and health of people at the event.[114] Mobile and drone technology to optimize disease surveillance and healthcare delivery is being evaluated and developed.[114] Dialogue with various community leaders of 'akahras' (sects) pre-determines the order of ritual baths.[18,21]

Preventing stampedes at the Hajj

With millions of pilgrims performing their religious rites close together within restricted space and within a specific short time period, crowd movement and flow will always be hindered, and disasters are inevitable. Previous Hajj pilgrim stampedes included 1,426 deaths in a 1990 due to stampede following a tunnel fire, and a similar Jamaraat Bridge incident in 2006 resulted in 346 pilgrim deaths. Since then the Saudi Arabian authorities have taken steps to improve the infrastructure and procession routes for pilgrims. This has led to a redesigned Jamarat Bridge which was completed in 2013.[115] New levels have been built at the Jamaraat and pilgrims are able to go to the second and third floors to perform the stoning rituals, and this has eased congestion.

Following the 2015 Hajj stampede and crane crash incidents, the Saudi Arabian authorities have made a $100 billion investment to expand the Hajj rites' infrastructure to accommodate needs of the ever-increasing numbers of pilgrims. According to the country new vision 2030 the number of Umra/Hajj pilgrims will increase to 15/2.2 million by 2020 and 30/4.5 million by 2030 (Kingdom of Saudi Arabia Vision 2030.[116] This includes: increased capacity of the 2 main airports receiving pilgrims in Jeddah and Madinah; increasing the holding capacity of the Grand Mosque in Makkah from 600,000 pilgrims to 2.5 million by 2020; building of a high-speed railway link from Mina to Medina, and a fast train link between Hajj terminal in Jeddah and Makkah. Also, being taken forward is innovative technology and crowd simulation models, to evaluate optimal ways of grouping and scheduling pilgrims and crowd management.[117] Use of modern technologies such as satellite imaging and CCTV cameras to monitor and direct flow of pilgrims is being developed to improve the safety and health of people at the event. To deal with the growing numbers of pilgrims, electronic bracelets which are water resistant will be provided to each pilgrim. The e-bracelets have a barcode where pilgrim's biodata and health information is stored including address of residence in the Kingdom. The e-bracelet has prayer times alert and a compass pointing the pilgrims to where they should face when they pray.[117] The annual Hajj provides unique opportunities for research on crowd behaviour and control.

REDUCING MORBIDITY AND MORTALITY FROM HEAT RELATED DISORDERS

Reducing heat-related morbidity at the Hajj

The Kingdom of Saudi Arabia (KSA) Ministry of Health (MoH) recommends several preventive measures to minimize both the communicable and non-communicable health burden, including heat disorders, among pilgrims during the Hajj.[97] One recommendation is that pilgrims use of umbrellas when walking in areas exposed to direct sunlight. Umbrellas will be distributed to each pilgrim on arrival at the Jeddah International Airport Hajj Terminal and at Hajj premises at no cost

to the pilgrims by both the Ministry of Health and other non-governmental organizations. Umbrellas that are equipped with fans are also being developed.

Pilgrims also receive health education and pictorial messaging advising them on the importance of protection from heat and sun exposure and keeping well hydrated.[118] Ongoing investments include air-conditioning unit being added to tents, and fans that spray water are being installed across the pathways between tents and camp sites. The marble surroundings at the Grand Mosque in Makkah are equipped with a cooling system that works on all levels. Huge folding umbrellas are installed in the courtyards of the 2nd Grand Mosque in Madinah. Other measures being taken are: pedestrians being distanced from vehicle. provision of shaded roads and rest areas, and provision of ample amounts of quality drinking water in all Hajj locations, and easy access to health services.

Tokyo 2020 Olympics

Preparations for 2020 Tokyo Olympics, Japan are underway. During the heat wave in Japan in July 2018, where temperatures reached 41 degrees centigrade, 22 000 people, half of them elderly, were reportedly taken to hospital with symptoms of heat stroke.[119-120] Preventing related heat illness in the anticipated hot climate of the Tokyo 2020 Summer Olympic Games[121] will be a priority issue for organisers in addition to the focus on infectious diseases.[122,123]

REDUCING RISK OF SPREAD OF INFECTIOUS DISEASES WITH EPIDEMIC POTENTIAL AT MASS GATHERINGS

Current global infectious threats to global health security are listed in **Table 5**. Media and World Health Organization (WHO) attention on Zika virus transmission at the 2016 Rio Olympic Games and the 2015 Ebola virus outbreak in West Africa had diverted the attention of global public health authorities from other lethal infectious diseases with epidemic potential.[124] For the hajj and other MGs appropriate pre-travel advice on hygiene measures[125-128], wearing of face masks and recommendations for mandatory and optional vaccines for prevention of infections are issued by local public health authorities and the WHO. Occasionally those in charge in the countries of origin face hurdles in the implementation of these measures [81,129] or issues regarding reduced immunogenicity of vaccines due to interactions between vaccines.[130] Although there have been no global outbreaks of meningococcal disease post Hajj for decades, there remains a high level of awareness of the possibility of outbreaks at all MGs.[81,131,132,133] Increasingly attention is being focussed on spread of airborne infections such as influenza, pneumococcus, measles and pertussis. [85, 128]

631 The highly lethal Middle Eastern respiratory syndrome coronavirus (MERS-CoV) continues to
632 circulate in Saudi Arabia[72,73] and it remains in the top ten WHO Research and Development
633 Blueprint list of infectious diseases, likely to cause major epidemics.[133] The 2015 MERS-CoV
634 outbreak in South Korea, in which 184 MERS cases including 33 deaths occurred in 2 months, was
635 imported from the Middle East by a South Korean businessman who had travelled to Saudi Arabia.[72]
636 Since then there have been calls for international community and Middle Eastern countries to make
637 available resources for taking forward a "One Human-Environmental-Animal Health" global
638 network for proactive surveillance, rapid detection, and prevention of MERS-CoV and other
639 epidemic infectious diseases threats.[134,135] This should be aligned closely to the Sendai framework
640 for disaster risk reduction.[137] Whilst there have been several small cohort studies published on the
641 prevention, transmission and occurrence of and bacterial respiratory tract infections in Hajj
642 pilgrims,[76] further research on large cohort studies of pilgrims from various geographical regions
643 are needed to provide a comprehensive evidence base on the risk factors, transmission dynamics,
644 pathogenesis, impact on health services, management outcomes and globalisation upon their return
645 to their home countries. [76,137] The acquisition of MERS-CoV has not yet been a major issue at the
646 Hajj, and surveillance and screening of pilgrims who fall ill after returning from Hajj is required due
647 to its continued circulation in Saudi Arabia.[72,73]

648 A large number of pilgrims to Saudi Arabia come from countries which currently have ongoing
649 conflicts, providing for emergence and transmission of emerging and re-emerging infectious
650 diseases. Many other pilgrims are from Asia, China, Europe, Africa, Middle East and Pacific regions
651 which are endemic with antibiotic resistant bacteria (CROs), multi-drug-resistant typhoid, multi-
652 drug-resistant TB, drug resistant malaria, drug resistant influenza, typhoid, cholera, Lassa fever,
653 Ebola, Monkeypox, Dengue, Yellow fever and other infectious diseases.[133]
654
655 Defining the public health risks, threats and consequences of these at mass gatherings will require
656 multi-national studies of pilgrim cohorts using similar methodology so that accurate surveillance,
657 transmission and impact data can be ascertained, compared and used for mitigating risk of global
658 spread. The Saudi Arabian government continuously reviews global threats and strengthens
659 surveillance systems operating at the Hajj strengthened.[63] (Alotaibi, et al 2017). Meanwhile
660 promoting appropriate personal prevention measures such as face masks personal hygiene
661 measures [118,126,129,134,136] and travel-related relevant vaccines such as influenza, polio, measles,
662 meningococcal meningitis and invasive pneumococcal disease, yellow fever, cholera, typhoid,
663 tetanus, diphtheria, rabies and other infectious diseases, should remain a priority.
664

TAKING FORWARD CROSS-CONTINENTAL COLLABORATIONS ON MASS GATHERING MEDICINE

There are other more country-specific religious mass gathering events which attract a smaller number of pilgrims from neighboring 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.[137] In West Africa, each year upto 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[138] the largest religious MG in West Africa. This attracts pilgrims from outside Africa and has the potential for globalisation of local endemic infectious diseases.[138]

A more collaborative approach for research on CDs and NCDs including heat disorders and disasters between local and international researchers and organisers of MG events is required. The recent creation of the Africa Centers for Diseases Control (Africa CDC) [139] by the African Union with its five regional CDCs in Gabon, Egypt, Nigeria, Kenya and Zambia the Africa CDC has created a major opportunity for improving coordination and public health capacity building initiatives in partnership with organisers of sporting and religious MG 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[134-136] should be adopted in partnership with Africa CDC. This initiative should aim to define the risk and threats to global health security and help limit the risk of outbreaks and spread of zoonotic infections such as Rift Valley Fever (RVF), MERS-CoV, viral haemorrhagic fevers, Ebola and others across both humans and animals. This risk was illustrated dramatically by the RVF outbreak in Jizan, Saudi Arabia in 2000[134] 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 development of a strong evidence base for Public Health Planning and Health Services around mass gatherings (**Table 6**). Whilst the formalisation of Mass Gatherings Medicine has led to increase in research studies into specific health issues affecting pilgrims at the Hajj, these have not been forthcoming from the Kumbh Mela and other MGs. Current research outputs from MG events are focussed on small studies of pilgrims from individual countries and the data are not generalisable nor have any outputs changed global policy. There remains an important need for more coordinated action by a

global coalition of interested partners to share experiences from various MG events, gather and translate appropriate evidence base into public health policy and drive the best health promotion and educational policies. The creation of a MGM specialist society or formal network, with a dedicated journal may generate more frequent dialogue and enhance international collaborations on MGM. There also remains a need for the conduct high quality studies appropriately designed and adequately powered utilising pilgrims from several geographical regions, to provide data that stands up to rigorous scientific review. With advances in technology and closer monitoring of pilgrims at the Hajj the opportunity for large cohort studies of attendees of mass gathering events. These could focus on current priorities for infectious diseases, including neglected tropical diseases[140], non-communicable diseases, mental health, heat disorders (**Tables 5 and 6**). With widespread availability of next generations sequencing, other molecular methods, genotyping and phenotyping, analyses of health risks amongst large population cohorts and conduct appropriate research to obtain an evidence base and produce WHO approved guidelines which will be useful for countries which host Mass Gatherings events.

Structured, real-time interoperable surveillance and reporting systems are required to conduct active surveillance of communicable and non-communicable diseases during MGs.[141] The continuing threat of new emerging and re-emerging infectious diseases with epidemic potential positions MGM as a one-stop surveillance platform for emerging diseases. [141] This would be an important public health deliverable of MGM. In addition, diseases targeted by WHO for elimination like polio are still endemic in some countries from where pilgrims originate to attend MG events like Hajj offering opportunities for research and evaluation of polio public health portfolio.[142] Increased investments in the field of MGM research are required for obtaining an accurate evidence base for development of accurate prevention, management and control guidelines to protect the health of attendees of MGs and the of local host country populations through optimal public health services.

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LEGENDS TO TABLES

Table 1
Historical Evolution and Formation of the Speciality of Mass Gathering Medicine

Table 2
Health risks and hazards associated with mass gatherings

Table 3
Key considerations related to setting up and implementing communicable disease alert, response, and operation plans for mass gatherings

Table 4
Mass casualties at Mass Gathering events (2013-2018)

Table 5
Current priority infectious diseases concerns

Table 6
Needs and opportunities for cross continental multidisciplinary research and training

Table 1

Historical Evolution and Formation of the Speciality of Mass Gathering Medicine

- 2000-2009: Virtual networks on mass gathering events, collaborations on MGs and public health issues of significance to global health security. The concept of Mass Gathering Medicine as a specialty emanated from discourse on the 2009 Hajj held during the 2009 HIN1 influenza pandemic.
- 2010: Launch point for mass gatherings medicine: October 23-25: The Jeddah Declaration on Mass Gathering Medicine. This was made at the Saudi Arabian Ministry of Health and The Lancet Infectious Diseases 1st International Conference on Mass Gatherings Medicine, held on in Jeddah.
- 2011: March 9th-10th: Support at the 35th meeting of the Arab League health ministers
- 2011: October 2nd-5th: Endorsement at the WHO EMRO Regional meeting health ministers in Cairo, Egypt.
- 2012: January: Review at WHO Executive Meeting
- 2012: May 27: Endorsement of MGM by WHO World Health Assembly 130th executive board
- 2012: September: WHO sets up the Global Centre for Mass Gatherings Medicine in Riyadh as a WHO collaborating centre
- 2013: September 21st-23rd: 2nd International Conference on Mass Gatherings Medicine in Riyadh
- 2014: April 28th-29th: 3rd International Conference on Mass Gatherings Medicine held in Riyadh
- 2014: May 27th: Formalization of the new discipline of Mass Gatherings Medicine as a discipline at a forum held at the World Health Assembly of Ministers of Health. This was twinned with the launch of the 2014 Lancet Series on Mass Gatherings Medicine (The Olympic 2012 Games in London and the 2012, the 2012 European Football Championship finals (Euro 2012), and Hajj pilgrimages 2012 and 2013)
- 2017: October 23rd-25th, 2017: The 3rd International Conference on Mass Gatherings Medicine held in Riyadh.
- 2018: November 22nd-23rd: International Conference on Mass Gatherings Medicine held in London.

Table 2

Health risks and hazards associated with mass gatherings

- Transmission of Communicable diseases including antibiotic resistant bacterial infections and sexually transmitted diseases.
- Water and sanitation related disorders
- Non-Communicable diseases and exacerbation of co-morbidities

  (eg Diabetes, hypertension, COPD, Cardiovascular events)
- Mental health and psycho-social disorders
- Thermal disorders including heat hyperpyrexia, heat stroke and dehydration
- Stampedes
- Accidents, Trauma, Crush injuries
- Terrorist incidents (Bio and chemical warfare threats, Explosives and Bombs)
- Alcohol and substance abuse

Table 3

Key considerations related to setting up and implementing 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.
- Identifying patients at risk and early intervention, identification of communicable diseases increasing of contacts, potential quarantining of the population at the event
- Medical care planning and guidelines (Preventative medicine, mandatory vaccinations, food management, water management and waste management, identification of local physical and fire hazards)
- Public health measures -water protection and provision, food protection and provision, syndromic surveillance
- Emergency services: Emergency planning and response (Rapid access to injured or ill patients; Provision of triage in the field and at aid stations; Providing on-site care for minor injuries and illnesses; Effective and timely stabilizing and transporting those patients requiring evacuation).
- Disaster medicine, Trauma and triage and level of care.
- Mobile units, Health stations and designated hospitals
- Use of modern technologies for diagnosis/detection, data collection and analyses, rapid communication, data collection, sharing and monitoring.
- Updating travel guidelines, including vaccinations, for each specific MG event

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1278 **Mass casualties at Mass Gathering events (2013-2018)**

MG Event (Ref)	Date	Disaster type	Casualties
Hajj (Karimi F et al 2015)[84]	2015 (Sept 11)	Crane at building site collapsed onto the Grand Mosque in Makkah	111 pilgrims died and 394 injured
Hajj (Saudi MoH, 2015)[85]	2015 (Sept 24)	Stampede in Mina at the intersection, leading up to the Jamaraat Bridge	769 pilgrims died and 934 injured
Kumbh Mela (David & Roy)[21]	2013	Stampede at railway station	37 pilgrims died
Kumbh Mela Greenough PG (2013)[22]	2015	Stampede at banks of river Godavri	27 pilgrims died
Boston marathon (Biddinger P et al 2013)[89]	2013 (April 15)	Terrorist bomb attack -two improvised 'pressure cooker' explosive devices)	3 people killed and 264 injured
Shanghai New Year celebrations (Dong et al 2017)[90]	2014 (Dec 31)	Stampede between Chenyi Square and the platform of the Bund	36 people died and 116 injured
Manchester Music concert (Singer Arian Grande) (Torjesen and Gulland, 2017)[87]	2017 (May 22)	Suicide bombing-Explosive device in the entrance foyer area of Manchester arena	23 people died and 139 injured
Las Vegas outdoor Harvest music festival in Nevada (Campion EW et al 2017)[86]	2017 (October 1)	Mass shooting by a gunman perched on the 32nd floor of a nearby Las Vegas hotel	58 people died and 851 injured

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Table 5: Current priority infectious diseases concerns which threaten global health security

- Tuberculosis
- Invasive Meningococcal disease
- Invasive Pneumococcal disease
- Antibiotic resistant bacterial, viral and protozoal infections: (Carbapenem-Resistant *Escherichia coli*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa; Klebsiella pneumoniae*; Vancomycin-resistant *Enterococcus faecium*, Fluoroquinolone resistant *Salmonella typhi*, and *Shigella spp*; 3rd generation cephalosporin-resistant and fluoroquinolone-resistant *Neisseria Gonorrhoeae*; Methicillin-Resistant *Staphylococcus Aureus*; Penicillin resistant *Streptococcus pneumoniae*; Ampicillin resistant *Haemophilus influenzae*; Multi-drug resistant and Extensively drug resistant Tuberculosis); drug resistant Influenza A, ARV resistant HIV and drug resistant *Plasmodium falciparum*).
- Cholera
- Typhoid
- Diphtheria
- Pertussis (whooping cough)
- Pandemic influenza
- Middle East Respiratory Syndrome Coronavirus (MERS-CoV)*
- Severe Acute Coronavirus (SARS-CoV)*
- Measles
- Yellow fever
- Other Viral haemorrhagic fevers (e.g. Marburg, Ebola, Lassa, Crimean Congo hemorrhagic Fever, Rift Valley fever, West Nile fever, Dengue)
- Polio (Wild-type polio virus)
- Zika*
- Dengue
- Nipah and henipaviral diseases*
- Rift valley fever*
- Ebola virus and Marburg virus disease*
- Lassa fever*
- Chikungunya*
- Crimean-Congo haemorrhagic fever
- Sexually transmitted diseases
- Malaria
- HIV

*WHO Blueprint priority disease

Table 6

Needs and opportunities for cross continental multidisciplinary research and training

- Developing a stronger evidence base for Public Health Planning and Health Services around mass gatherings. - coordination and collation of experiences of the organizers and hosts of the recurrent annual MG events such on a range of communicable and non-communicable diseases can provide ideal platforms to take the formal discipline of MGM forward, conduct appropriate research to obtain a strong evidence base and update MG specific and individual guidelines.
- Need for high quality studies, appropriately designed and adequately powered to provide data that stands up to rigorous scientific review. Obtaining quality data which can drive forward the public health and health promotion agendas.
- Mass casualty incidences: Stampedes, crush injuries and fires- causes, streamlining flow, crowd behaviour, pilgrim psychology and measures for reducing risk
- Thermal disorders – underlying factors, pathophysiological studies, and effectiveness of measures for reducing risk
- Infectious diseases with epidemic potential (Table x) – surveillance, prevalence, transmission, management, prevention (vaccines/chemoprophylaxis/infection control) and cohort followup studies.
- Antibiotic resistant bacteria - surveillance, prevalence, transmission, management, globalisation and long-term cohort follow-up studies (pre-travel, during MG event and post MG event).
- Non-communicable diseases and co-morbidities – defining the scale of the problem, impact on pilgrim health and reducing risk of increased morbidity, hospitalisation and mortality.
- Current advances in molecular methods, genotyping and phenotyping for analysis of health risks (both CDs and NCDs), underlying genetic and other risk factors using large pilgrim cohorts.
- Real-time interoperable surveillance and reporting systems are required to conduct active surveillance of communicable and non-communicable diseases during MGs
- 'Big Data' collection, repository, sharing and analyses
- Creation of a MGM specialist society or proactive global network, to enable frequent dialogue and enhance international multidisciplinary surveillance, research and training collaborations on MGM.