

Mass Gatherings Health 3



Non-communicable health risks during mass gatherings

Robert Steffen, Abderrezak Bouchama, Anders Johansson, Jiri Dvorak, Nicolas Isla, Catherine Smallwood, Ziad A Memish

Mass gatherings (MGs) have been associated with high rates of morbidity and mortality from non-communicable diseases, accidents, and terrorist attacks, thus posing complex public health challenges. We assessed the health risks and public health responses to MGs to identify an evidence-based framework for public health interventions. Human stampedes and heat-related illnesses are the leading causes of mortality. Minor traumatic injuries and medical complaints are the main contributors to morbidity and, particularly, the need for onsite medical care. Infrastructure, crowd density and mood, weather, age, and sex determine the risks to health. Many predictive models for deployment of medical resources are proposed, but none have been validated. We identified the risks for mortality and morbidity during MGs, most efficient public health interventions, and need for robust research into health risks for non-communicable diseases during MGs.

Introduction

In the past decade, concern has been increasing about the health risks related to mass gatherings (MGs).¹⁻⁵ Such gatherings can result in high rates of morbidity and mortality from communicable and non-communicable diseases, injury, and terrorist attacks.¹⁻⁸ These events, therefore, pose a complex public health challenge locally, nationally, and internationally.¹⁻¹² Strategies for government preparedness and those of various international agencies have focused mainly on the risks of communicable diseases during MGs because of their potentially huge consequences, and less on documenting risks introduced by non-communicable diseases.^{2,4,7,10}

Non-communicable diseases and injuries have caused more deaths and morbidity than have communicable diseases.^{6,8,13,14} Human stampedes or crush injuries have resulted in more than 7000 deaths and 14000 injured people over 27 years.^{8,15-19} At the summer Olympic Games in Atlanta, GA, USA, more than 1000 people received medical care for heat-related illnesses.^{13,20} During the pilgrimage to Mecca, Saudi Arabia, in August, 1985, for example, 2000 cases of heatstroke were reported and more than 1000 of these individuals died within a few days.⁶ The incidence of severe acute cardiovascular events more than doubles during MGs that are associated with intense emotional stress—eg, sporting tournaments.²¹⁻²⁵ MGs have also been the target of terrorism, resulting in many deaths and injuries.^{26,27} The potential for major accidents (such as those seen during car racing, stadium events, and air shows) involving mass casualties is always present and might result in loss of life and widespread injury.

In addition to potentially life-threatening illnesses, MGs are associated with an increased incidence of trauma—eg, resulting from illicit use of drugs or alcohol intoxication.²⁸⁻³⁹ The acute challenge to health systems becomes apparent when these illnesses are added to the most frequent complaints—such as bruises, cuts, sprains, headaches, dizziness, asthma exacerbations, and

abdominal pain—that require onsite medical care or transport to a health facility.^{22,29-41}

Several methods of intervention have been proposed to reduce the rates of morbidity and mortality from non-communicable diseases or injury during MGs.^{22,40,42-68} These include pre-event planning of the public health response, such as preparedness for onsite emergency medical care, and implementation of strategies and mitigation measures to minimise risks from terrorism or disasters.³⁹⁻⁶⁵ For these purposes, methods and sophisticated models for prediction of patient numbers and levels of care have been proposed to help decide the medical resources and staff deployment needed.^{24,67,69-76} Although these various approaches are now part of guidelines and recommendations, evidence for their effectiveness has yet to be assessed.^{57,62,77-81}

Our objective in this review is to address the health risks and public health responses to non-communicable diseases or injury at MGs so as to identify an evidence-based framework for public health intervention. For example, much information is available about security measures for terrorism at MGs, but little of this information specifically addresses medical or public health preparedness. This review is not an exhaustive review of the literature, but provides some suggestions for public health and medical preparedness for incidents that could occur at MGs.

Our review of published work, despite its limitations, established the following evidence. First, human stampedes and heat-related illnesses are leading causes of mortality during MGs.^{6,8,15-17} Second, minor traumatic injury and medical complaints are the main contributors to morbidity and onsite emergency medical care.^{29-40,66,82-85} Third, outdoor gatherings in developing countries,⁸ crowd density and mood,^{28,30,86-88} warm and rarely cold weather,^{13,29,30,32,41,89-91} young and old ages,⁹²⁻⁹⁴ and female sex^{30,50,92} were all associated with an increased risk of illness or injury. Fourth, predictive models for resource deployment and level of care have been developed to help medical planning, but so far none have been fully assessed and tested.⁷⁶

Published Online

January 16, 2012

DOI:10.1016/S1473-

3099(11)70293-6

This is the third in a **Series** of six papers about mass gatherings health

Division of Epidemiology and Prevention of Communicable Diseases, Institute of Social and Preventive Medicine,

University of Zurich, WHO

Collaborating Centre for

Travellers' Health, Zurich,

Switzerland (Prof R Steffen MD);

Division of Epidemiology,

Human Genetics and

Environmental Sciences,

University of Texas School of

Public Health, Houston, TX,

USA (Prof R Steffen); King

Abdullah International Medical

Research Centre, King Abdul

Aziz Medical City for National

Guard Health Affairs, Riyadh,

Saudi Arabia (A Bouchama MD);

Centre for Advanced Spatial

Analysis, University College

London, London, UK

(A Johansson PhD); Faculty of

Engineering, University of

Bristol, Bristol, UK

(A Johansson); Fédération

Internationale de Football

Association Medical

Assessment and Research

Centre (F-MARC) and

Schulthess Clinic, Zurich,

Switzerland (J Dvorak MD);

Global Capacities, Alert and

Response, WHO, Geneva,

Switzerland (N Isla MSc,

C Smallwood PhD); Preventive

Medicine Directorate, Ministry

of Health, Riyadh, Saudi Arabia

(Prof Z A Memish MD); and

College of Medicine, Alfaisal

University, Riyadh, Saudi

Arabia (Prof Z A Memish)

Correspondence to:

Prof Robert Steffen, University of

Zurich, Institute of Social and

Preventive Medicine,

Hirschengraben 84/E29,

CH-8001 Zurich, Switzerland

roste@ifspm.uzh.ch

Health risks

Several prominent health risks are attributable to environmental and host factors (table). Stampedes, weather and other environmental conditions, emotional stress, and terrorism were chosen because they are important contributors to morbidity and mortality. Additionally, these require intense planning in terms of medical and public health preparedness and when measures to mitigate risks need effective intersectoral coordination.

Human stampedes are the most feared disaster during MGs because they are frequent and associated with a high fatality rate.^{8,15–18} Hsieh and colleagues⁸ identified 215 human stampedes from 1980 to 2007. They occurred mainly during religious gatherings, but also during sports, musical, and political gatherings. Stampedes resulted in a mean of 33 (SD 128) fatalities and 79 (257) injuries per event.⁸ In multivariate analyses, outdoor MGs in developing countries were independently associated with increased mortality rates.⁸ We identified two more stampedes in the past 4 years, both in Asia, that resulted in 410 fatalities.^{18,19} In the grey literature,⁹⁸ 13 further human stampedes were reported, most associated with high numbers of casualties.^{18,19} The mechanisms that lead to crowd disasters have not been fully elucidated,^{8,18} but results from previous empirical studies^{95,96} of a crowd disaster have shown a series of dynamic flow patterns with sharp transitions between them (smooth to stop-and-go-flow and further to crowd turbulence). Such a mechanism could result in crowd

disasters and has been postulated to be a generic feature of many MGs. Two cofactors have been postulated—failure to address crowd size and type compared with infrastructure and a triggering event.^{8,18} This trigger could be a real threat (eg, a fire or a bomb blast), but is often a virtual threat (eg, rumours that something dangerous is about to happen or even a sudden change in weather). For example, a stampede resulting in about 1000 deaths in Iraq in 2005 was triggered by the false rumour of a suicide bomber.¹⁶

Panicking participants might be the main cause of stampedes. Contrary to popular belief, social order does not break down, even when individuals fear for their lives. For example, in-depth interviews with evacuees from the World Trade Center in 2001 showed that people behaved in a civilised, orderly, and calm manner, even though they realised the extreme danger they were in.⁹⁹

Weather and other environmental conditions, including warm^{6,13,20,89,91} and cold temperatures,^{36,39,100,101} precipitation,⁸⁸ and pollution³⁵ can contribute to illnesses, including life-threatening heatstroke, hypothermia, trauma, and dyspnoea. A review of the effect of warm weather showed a strong correlation between high temperatures or humidity and the use of medical care during MGs.⁸⁹ A similar relation between health outcomes and warm temperatures was previously noted during the Hajj.^{6,91} Findings from studies in Mecca showed that an extreme environmental temperature led to a major disaster—more than 1000 deaths from heatstroke in a few days and

Event	Disease or injury	Risk factors	Emergency medical care	Mitigation measures
Human stampedes ^{8,18,19,95,96}	Traumatic asphyxia, crush syndrome, and rhabdomyolysis	Outdoor gatherings, developing country, overcrowding, inadequate infrastructure with presence of bottlenecks, and poor planning	Airway management, basic life support, advanced cardiac life support, EMS transport to emergency department	Crowd control measures (including real-time crowd sensing and tracking), crowd traffic control at bottlenecks, well marked entry and exit directions, and suitable ingress and egress routes for emergency personnel
Warm weather ^{6,13,20,89,91,97}	Heat cramps, heat exhaustion, and heatstroke	Warm and humid weather, old age, pre-existing cardiovascular, psychiatric, and pulmonary diseases, and drugs that interfere with heat dissipation	Transport to a cool place, and if core temperature is higher than 40°C start immediate cooling (eg, ice, fan, and wet sheet), basic life support, and EMS transport to emergency department	Preparation of air-conditioned places (cooling shelter), ensure easy and safe access, spend a few hours in a cool place, use fans where possible, increase intake of fluids, and avoid exercise
Emotional stress ^{21–25}	Acute cardiovascular events: chest pain, acute myocardial infarction, arrhythmia, and cardiac arrest	Emotional stress and known coronary artery disease	Basic and advanced cardiac life support, acute coronary syndrome management, EMS transport to emergency department	Avoid stress, cardiology advice for stress control, advanced cardiac life support certified staff, and provision of automated defibrillators
Traumatic injuries ^{29,31–34,85}	Head injury, eye injury, fractures, and skin cuts	Substance abuse, alcohol, outdoor event, precipitation, and snow	Basic first aid, stabilisation of spinal injury, and early transfer	Restrict or prohibit access to alcohol and drugs, public health intelligence, and enhance surveillance
Medical complaints ^{29–33,85}	Headache, abdominal pain, dizziness, syncope, breathing difficulty, and asthma	Alcohol, noise, pollution, and known asthma and allergy	Basic first aid and supportive treatment	Reduce air pollution, plan for chronic diseases, and provide medical care onsite
Disasters due to accidents or terrorism ²⁷	Mass casualty, trauma, burns, and blast injury	High visibility event, air show, and car racing	Activate disaster plan, triage, and evacuation and transport	Plan for mass casualties and disasters, intersectoral coordination, and enhance surveillance and intelligence

EMS=emergency medical services.

Table: Non-communicable health risks and health interventions during mass gatherings

more than 18 000 people needing treatment in emergency departments for heat exhaustion.^{6,91} Although much less severe, heat-related illnesses have been reported at other religious MGs, such as papal visits in San Antonio, TX, USA; they represented nearly 90% of the demand for medical care.¹⁰² Heat was also identified as a relevant factor with respect to the need for medical care during other sporting,^{13,20} musical,³⁰ and traditional^{29,32,103} MGs. The heat index, a variable that combines measured air temperature and humidity, was useful for prediction of the demand for medical care.⁹⁰ Taken together, these findings suggest that warm weather is the most crucial environmental factor. This finding is important because sophisticated climate models have been used to predict more hot days with extreme temperatures worldwide in the coming years.^{6,89}

Cold temperatures can also be associated with health problems.^{32,39,87,88} A sudden drop in temperature from 29°C to 13°C, such as during the papal visit near Denver, CO, USA, with pilgrims hiking 14 miles at high altitude, resulted in a huge increase among the 500 000 attendees seeking onsite medical care.^{39,101} A similar finding was noted in New York, NY, USA, at temperature ranges of 10–15°C.¹⁰⁴ Other meteorological factors played a part during the Woodstock Festival, Bethel, NY, USA, in 1969—the rain flooded the terrain, which became slippery, resulting in many injuries that included fractures.⁸⁸ Floods, high winds, and other extreme weather conditions contribute to morbidity and mortality at MGs. There are very few data for the effects of pollution at MGs; however, during the Olympic Games in Beijing, China, in 2008, a city known for its high air pollution, restriction on transportation reduced the average number of outpatient visits for asthma compared with control periods (12·5 per day to 7·3 per day, respectively; relative risk 0·54, 95% CI 0·39–0·75). This finding suggests that air pollution might contribute to morbidity during MGs and should also be taken into consideration in planning medical care.³⁵

During the World Cup in Germany in 2006, the incidence of cardiac emergencies in the host population watching its own team was 2·66 times higher than during a control period,²¹ hence establishing a relation between emotional stress and life-threatening cardiovascular disorders. These disorders, including acute myocardial infarction, arrhythmias, and cardiac arrest, were particularly frequent in people with known coronary artery diseases.²¹ Cardiac arrest was reported to be fairly frequent in the soccer stadiums.²⁵ In a survey of 26 games in college stadiums, chest pain was the main medical reason for transport to hospital and emergency medical care.²² Importantly, despite difficulties in administration of appropriate cardiopulmonary resuscitation and defibrillation, nearly 80% of affected spectators regained spontaneous circulation and 60% survived without neurological deficits after resuscitation.^{24,25} These findings warrant the presence of qualified staff who are trained in advanced cardiac life support and the installation of automated defibrillators at

MGs.^{22,23} Fédération Internationale de Football Association (FIFA) has made the provision by football clubs of an appropriate number of defibrillators to the spectator sections of its stadiums a requirement.

MGs are often cited as targets for terrorism;^{3,11,105,106} the reasons are high densities of people, international visibility, and symbolic means through which terrorists might amplify the effects of their actions^{107,108}—eg, the abduction of athletes during the Olympic Games in Munich, Germany, in 1972.²⁶ From a public health perspective, however, the precise level of threat to MGs is not the only consideration in planning and preparedness; the potentially devastating public health consequences of terrorism mean that it cannot be excluded from the overall public health plans for MGs.

Although successful terrorist attacks have been sparse, they have shown that preparation for the range of possible consequences is difficult. For instance, because hostages were taken by an organised group, the highly coordinated terrorist attack during the 1972 Olympic Games in Munich (17 deaths) was different from the single-handed attack on the 1996 Olympic Games in Atlanta (two deaths and more than 100 injured people),²⁷ Iraq Ashura bombings (nearly 200 deaths and more than 500 injured), and the bombing during the 2010 World Cup in Kampala, Uganda (74 deaths and 70 injured). The scenarios are endless in terms of planning security for MGs.

Health outcomes associated with terrorism are not restricted to the effect of successful attacks. MGs are settings for panic, rumour, and hoax, and bomb scares have been the source of lethal stampedes.¹⁶ In the event of a terrorism scare, the rapid and safe evacuation of large numbers of people from areas of concern presents additional difficulties for medical services. As shown during the 1997 Grand National horse race in the UK, additional challenges associated with mass evacuations are not straightforward, often requiring spectators to abandon their belongings (including treatment for pre-existing medical disorders) and emergency procedures that can cause high levels of stress and related illnesses.

Risk factors

Specific characteristics of MGs that might increase the vulnerability of participants include infrastructure, duration and type of event, and crowd density, mobility, and mood. However, different types of gatherings will have different risk profiles and draw visitors with different demographic characteristics, precluding any direct comparison.

The need for medical care during sports events is lowest when spectators have seats, whereas mobile or standing populations have an increased health risk.^{49,80} No correlation was noted between the number of participants and the need for medical care.⁷⁴ However, the density of the crowd (number of people per m²) was more relevant as a health risk than was the number of people. In terms of participants' safety at MGs,

overcrowding, leading to crowd disasters, almost always occurs at bottlenecks where the crowd is compressed—eg, the stampede during the Love Parade in Duisburg, Germany, in 2010, led to 21 fatalities and 300 injuries. The site was designed for 250 000 participants, but had 1.4 million; a narrow tunnel near the entrance was a bottleneck and thus the place for the catastrophe.

Crowd mood can be affected by the type of MG and use of drugs and alcohol, which can further potentiate the risks of injury and illnesses.^{28,83,109,110} In sporting and music events, rivalry might deteriorate into aggression, whereas in other gatherings aggression might be deliberately planned, for instance during political demonstrations.^{28,85,110} Reports from the Woodstock Festival show that the mood might change depending on the type of music and on meteorological conditions. Alcohol and drugs such as amphetamine, particularly 3,4-methylenedioxy-N-methylamphetamine (MDMA or Ecstasy), and other hallucinogens are a common cause of injury and illness during rock and rave music concerts.^{28,83,109,110} In one study, nearly half the patients treated during a rock concert had admitted using illicit drugs or alcoholic beverages.⁸³

By contrast with previous reviews,^{49,80} we noted that women and very young and old people might be more vulnerable during MGs than are other categories of the population.^{6,30,50,91–94,111} Women are mainly the victims of stampedes¹⁹ or seek medical care, although no immediate explanation was provided for this apparent sex discrepancy.^{29,30,50} Likewise, children are two or three times more likely than are adults to present for medical attention and have different medical problems.^{92–94} The results of an early survey of children attending the summer Olympic Games in Atlanta showed that when

the children presented to the emergency department, they were sicker and more likely to need hospital admission than were typical participants presenting to the emergency department.⁹⁴ In another study, one of three children seeking medical care were not accompanied by their parents. Although in this study, the degree of illness or injury was low, it increased the complexity of the management of children at MGs.⁹² Specific measures, including staff qualified in paediatric emergencies and obstetrics, should be an important component of onsite medical-care planning when children are likely to attend. Older adults are most susceptible to the effects of heat waves in temperate climate regions or during the pilgrimage to Mecca in summer seasons.^{6,91–94,111} This increased susceptibility is partly attributable to ageing, which reduces tolerance to heat so that thirst is sensed late, increased latency to trigger sweating, and a reduced number of sweat glands, thus hindering the most important mechanism of heat dissipation.¹¹² Additionally, old age is often associated with comorbidity, particularly cardiovascular diseases; a healthy cardiovascular system is a prerequisite for effective thermoregulation during heat stress.⁹⁷ Moreover, the presence of physical or cognitive impairment renders elderly people most vulnerable.¹¹¹ The proportion of cardiovascular deaths in the elderly population doing Hajj was 43% of all fatalities,¹¹³ by contrast with the estimated low rate (not more than one per 100 000) of cardiac arrests in the younger population attending sports events in Australia.³⁴

Mitigation measures and health intervention Surveillance

For robust and resilient MG planning, we identified some measures to be taken to prevent mortality and morbidity and reduce the burden to the public health system (table). Importantly, epidemiological data should be gathered for the region mainly with respect to communicable diseases. However, the same applies to surveillance of non-communicable risks—eg, road traffic accidents and injuries. For football competitions such as the EURO 2008⁷⁸ and the FIFA World Cup in South Africa in 2010, epidemic intelligence support was essential.¹¹⁴ FIFA's Medical Committee developed a checklist for the local organising committee and its medical staff that was based on the experience gained from past events. For the team doctors and FIFA and venue medical officers, a *Football Emergency Medicine Manual* was published before the World Cup. Additionally, the Centers for Disease Control and Prevention, Atlanta, GA, USA, have shown the importance of public health screening and surveillance, particularly with respect to heat-related events, and accidents. Also, enhancements to surveillance systems will increase the ability to detect, in a timely manner, any acts of terrorism involving the use of chemical, biological, or radioactive agents.¹¹⁵

For WHO Global Alert and Response see <http://www.who.int/csr/en/>
For Fédération Internationale de Football Association see <http://www.fifa.com/medical>
For Centers for Disease Control and Prevention see <http://wwwnc.cdc.gov/travel/yellowbook/2012/chapter-8-advising-travelers-with-specific-needs/travel-to-mass-gatherings.htm>

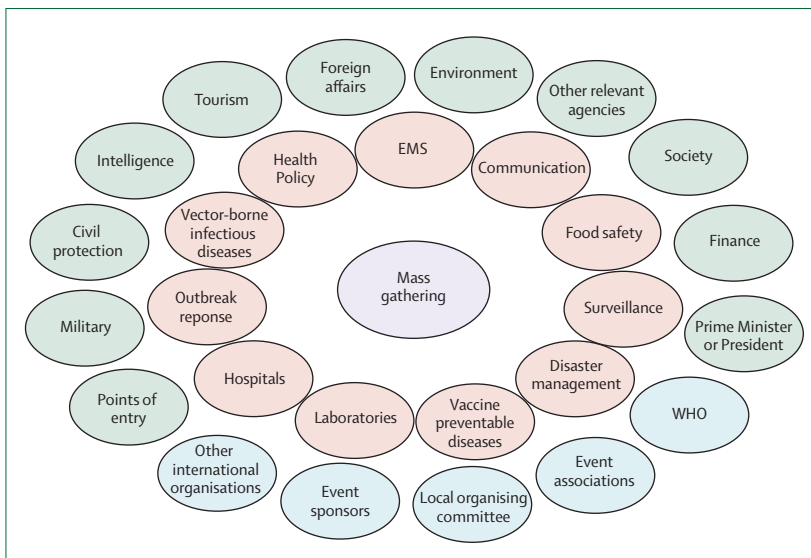


Figure: Public health and intersectoral coordination required for mass gatherings

EMS=emergency medical services. Pink=health-related stakeholders. Green=other national stakeholders. Blue=other stakeholders.

MG infrastructure

Human stampedes are preventable, providing mitigation measures are taken in advance.^{8,18} First, the entrances, exits, and other bottlenecks at the event site must be of sufficient size to ensure capacity. The capacity is dependent on the type of event and cultural and demographic factors, but as a general rule, the maximum throughput is about one person per s/m width—ingress and egress dimensions need to be designed accordingly. Second, if possible, scheduling should ensure that visitors arrive gradually over time rather than within minutes of the start of the event. Third, for large-scale MGs, vast amounts of resources are needed to control and guide the crowd in large areas. These areas can be divided into smaller subareas for the purposes of crowd control, as done during President Barack Obama's inauguration and the Hajj in the past few years.⁹⁵ Fourth, several measures are available that allow the analysis of crowd movement in real time with automatic processing of closed circuit television,^{95,96} tracking mobile phones,¹¹⁶ or counting participants at turnstiles and other access points. These live data feeds can be integrated into a crowd management plan so that potential difficulties can be detected or predicted and dealt with before they become dangerous situations.

Prevention of heat-related illnesses

Heat-related mortality and morbidity are preventable. Therefore, participants should be made aware of the dangers of heat during MGs. The risk of heat-related death is increased with old age and pre-existing illnesses, particularly cardiovascular, pulmonary, and psychiatric disorders.¹¹¹ Organisers of MGs should develop and implement health intervention strategies for these populations during warm weather. The recommendations should stress the factors that have been proven to be effective, including spending a few hours in a cool place.¹¹¹ Therefore, organisers should identify and prepare air-conditioned environments (eg. cooling shelters and buses) that could be used during the mass event, and ensure easy and safe access. The attendees should be informed about the location of the nearest places where they can keep cool and how they can access them. Additionally, fans should be used whenever possible, increased intake of fluids (such as provision of free potable water) should be encouraged, and unnecessary exercise should be avoided. Sun-protection advice such as the use of umbrellas, sunscreen, and protective footwear is also useful.

Emergency medical-care provision

Results from most studies are in agreement about the provision of emergency medical care onsite at MGs, but not about the level of care that might be needed.^{13,37,74,117} The reason for this disagreement is that the numbers of patients and the illnesses or injury acuity differ according to the type of MG. For instance, injuries might vary from severe head or spinal injury to simple bruising or cuts

Panel: Public health response to an emergency at a mass gathering

Emergency response plans for all types of hazards

An emergency response plan is needed to commit rapid and trained emergency resources, including first responders, quickly deploy medical provisions, and ensure well prepared hospital systems and facilities.²

Specific plans for mass casualty management

An event with mass casualties is defined by WHO as an event that generates more patients than the local resources can address and thereby needs emergency measures and specific preparedness.² The preparedness for mass casualty events should address trauma, chemical and radiological intoxication, food-borne and other communicable diseases, and psychosocial issues related to terrorism such as the worried-well individuals.

Coordination is needed to achieve:

- Standardised and rapid assessment and triage of critically injured individuals and people who are expected to survive
- Rapid care, including surgical care if necessary
- Rapid movement to successive echelons of health care, including relief for medical teams¹²⁰
- Management of events with mass fatalities^{79,121}

Intersectoral governance of command and control

Participation in this organisation should include all partners from different sectors (including health, security, military, and civil defence). The effective management of any incident with public health or medical implications will depend on a multiagency command and control structure, and the functions will be defined and training will be provided for each member in advance. An organisation responsible for implementing this structure should:

- Undertake integrated surveillance and risk assessments
- Undertake incident command function
- Define the type of health management that is likely to be needed in response to any possible incident
- Undertake and maintain communication for risk management

Search strategy and selection criteria

We searched Medline, Google Scholar, and Cochrane databases for original research published in English from January, 1970, to August, 2011, using the search terms "mass gathering(s)" AND, "human stampedes", "heat-related illness", "heatstroke", "heat exhaustion", "heat cramps", "temperature", "cardiac arrest", "trauma", "burns", "disaster", "mass casualty", and "terrorism". Other inclusion criteria were assessments of health interventions or outcomes as endpoints in studies of more than 1000 adults or children who were attending mass gatherings (MGs). The exclusion criteria were studies of MGs for political purposes, only communicable diseases, MGs with fewer than 1000 people, and not reporting health outcomes or public health response as endpoints; and reviews, policy and guidelines, editorials, and case reports. The studies were assessed according to criteria for observational studies—ie, namely the type of intervention or exposure, comparability of the baseline characteristics (if a comparison group was included), and the absence or presence of confounding factors. 588 references related to MGs were identified, of which 97 observational studies met the eligibility criteria for the assessment and were used in the narrative synthesis of the evidence. We also assessed the recommendations for health risks and interventions on the WHO Global Alert and Response, Fédération Internationale de Football Association, and the Centers for Disease Control and Prevention websites and cross-checked them for references used to formulate the recommendations.

that need to be sutured, or from simple headache to severe chest pain. These differences make the planning and deployment of medical resources in terms of

quantity, sophistication, and staffing levels very difficult to predict.^{22,42,50,56,64,66} To ease this process, scoring systems^{69,70} and increasingly sophisticated predictive mathematical models^{72,74,75,118} have been developed that include increasing numbers of variables—namely, weather, crowd numbers, mobility, and mood, and availability of alcohol and other drugs—that are known to increase the health risks, but so far none of these systems and models have been validated.^{49,74} Until appropriate models are developed and successfully tested, most of the medical requirements will still be based on historical data that are specific to each event.^{71,76}

Response teams and standard procedures

For modern injury preparedness, staff including physicians and equipment including ambulances must be available onsite. Forecasts of the onsite requirements should be discussed and based on appropriate risk assessments and training should be for the most likely scenarios. Procedures, such as triage algorithms, need to be specified with respect to evacuation priorities, transfer destinations, and sequence of care at the hospital.^{66,70,76,119}

Terrorism

Public health is most important in terms of detection and management of the response to terrorism. Measures for mitigation can therefore help to minimise the public health consequences of any terrorist action that evades the established prevention measures for the MG. This assistance relies on the preparedness of the planned public health services for the event and, equally important, the effective coordination and efficient communication between health agencies and other sectors, including security. The range of public health and other sectors that can be involved in a public health response during a mass gathering is shown in the figure. The panel shows the important factors that need to be considered during the implementation of a response to a large-scale public health crisis such as a terrorist act.

Future challenges and opportunities

Standard terms and definitions for the description of non-communicable health risks would be useful for future assessments of MGs. Perhaps the WHO MG manual (in preparation) will contribute to a more standardised discussion of these issues. More data are needed, particularly from the analysis of non-traditional (shopping centres and airports) and spontaneous MGs (political demonstrations and state funerals).^{79,122} The huge knowledge gaps relating to crowd psychology and MG settings need to be closed.⁸⁶ No one-size-fits-all solution exists for the mitigation of risks from non-communicable diseases at MGs. However, new rigorous research into the factors that increase the risks and best practices in the mitigation of those risks would contribute greatly to further understanding the complex dynamics of MGs.

Contributors

All authors formulated sections of the text in this review and searched for literature in their respective sections. AB provided the figure and table, and contributed to the revision of the review. RS prepared the initial draft and coordinated all further amendments. CS and NI contributed additional sections to the original submission about terrorism in MGs and assisted in the improvement to the finally accepted version of the review.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

We are most grateful to Maia Funk, University of Zurich, for assisting with compiling and editing the references.

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