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Mass Gatherings Health 6



Research agenda for mass gatherings: a call to action

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Public health research is essential for the development of effective policies and planning to address health security and risks associated with mass gatherings (MGs). Crucial research topics related to MGs and their effects on global health security are discussed in this review. The research agenda for MGs consists of a framework of five major public health research directions that address issues related to reducing the risk of public health emergencies during MGs; restricting the occurrence of non-communicable and communicable diseases; minimisation of the effect of public health events associated with MGs; optimisation of the medical services and treatment of diseases during MGs; and development and application of modern public health measures. Implementation of the proposed research topics would be expected to provide benefits over the medium to long term in planning for MGs.

Introduction

A mass gathering (MG), as defined by WHO, is “any occasion, either organized or spontaneous, that attracts sufficient numbers of people to strain the planning and response resources of the community, city or nation hosting the event”.¹ MGs can be spontaneous or organised and include sports events, social or cultural functions, gatherings of displaced populations due to natural disasters or war, and political or religious congregations.²⁻⁵ Major MGs are likely to involve communities from different parts of the world. Participants and host and home communities face health risks that are of international concern. Therefore, the control of infectious diseases and provision of medical services for non-communicable diseases and other risks to health are increasingly important in the planning for MGs. Risks commonly associated with MGs include health systems having to accommodate a surge in capacity; challenges to existing health interventions; introduction and transmission of non-endemic diseases during and after MGs; difficulties associated with risk communication to participants from different cultures; and those arising because of the high profile of some events, such as security risks.

International MGs can amplify the transmission of infectious diseases, and infections can spread from the home to the host community during travel to and from the event and from the host to the home community on return.⁶ Such events can pose substantial risks to global health security and present challenges for surveillance of the spread of such diseases to new ecological settings and vulnerable populations.⁷

In addition to risks of infectious diseases during MGs, non-communicable risks include cardiovascular diseases, environment-related heat injury, fire-related injury, illnesses related to use of drugs and alcohol, occupational injuries, trauma or crush injuries associated with stampedes, exacerbation of respiratory diseases, and crowd safety.⁸ Large MGs can also provide opportunities for terrorist activities.

In planning for MGs, international and local health authorities need to ensure that the strengthened public health systems and rapid responses to health risks are integrated with other important components of the overall event management. Effective public health policy should be based on evidence.

The organisation of international MGs generally requires provision of huge amounts of resources by the host country and the dividend of such high visibility is called legacy. This legacy should be measured not just in terms of absolute improvements (eg, new roads and ambulances) but also in terms of improvements to the public health system and society as a whole. For example, the legacies of strengthened integration of clinical or laboratory services, early warning or syndromic surveillance, and field epidemiology or response adopted for the past summer Olympics (Sydney, Australia, Athens, Greece, and Beijing, China)⁹⁻¹¹ are used routinely in the health systems.

Research agenda for MGs

The development of effective methods for, and improvement of, planning and handling of the health risks associated with MGs will strengthen global health security, prevent excessive emergency health problems and associated economic loss, and mitigate potential societal disruption in host and home communities. Such development requires credible evidence to support activities that can reduce the global effect of infectious diseases and address local public health issues related to morbidity and mortality resulting from non-communicable diseases during MGs. However, there are gaps in knowledge about many public health issues that contribute to effective planning.^{6,12,13} Therefore, a robust knowledge about illnesses, from basic scientific understanding to societal effects of infections and non-communicable diseases, is essential for modern public health practices and policy development related to the planning for MGs.

Several reports¹¹⁻¹⁵ and WHO planning and guidance documents^{1,16-18} have drawn attention to the importance

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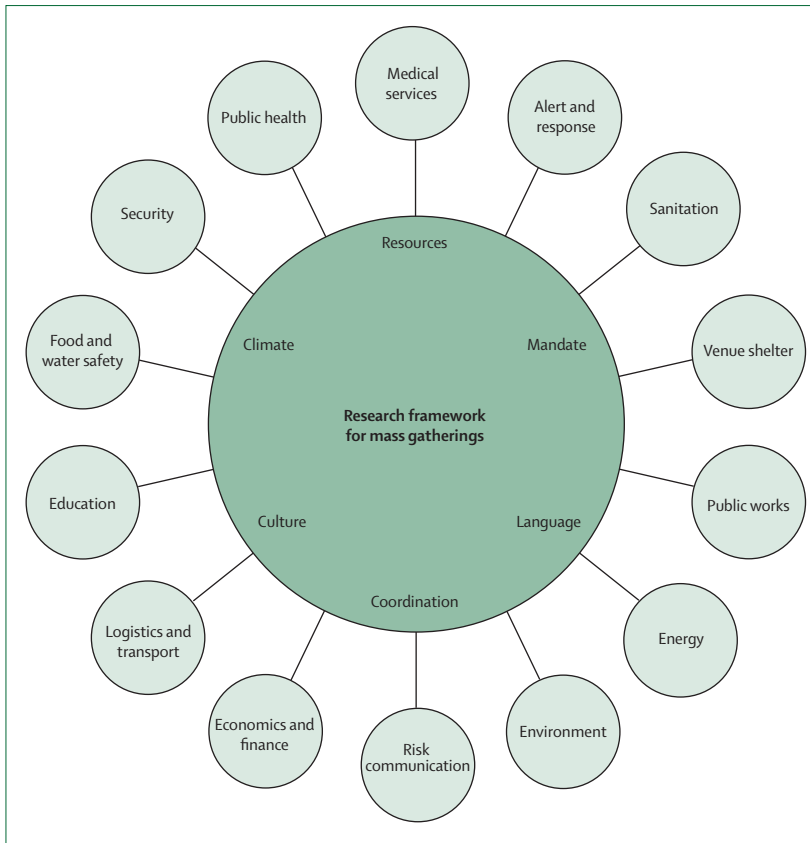


Figure: Multidisciplinary interactions for research into mass gatherings

of research into public health issues associated with MGs and identified those that need immediate attention. Despite these efforts, an overarching research agenda based on public health to address the gaps in knowledge in MG health has not yet been developed. Moreover, international coordination to prioritise and enable the funding and implementation of such an agenda has been lacking. The recent recognition and rapid development of MG health can provide focus on such issues.

Previously identified research priorities for MGs tended to focus on logistical issues relating to site security and emergency management, crowd control, and surge in the need for medical services.^{12,13} Other specialties tend to focus on each of the specific public health topics that are associated with MGs. Much research into existing and emerging infectious diseases is devoted to the development of rapid diagnostic methods, surveillance and response, and treatment and vaccines. Although a research agenda based on public health must be underpinned by basic science, applied science and operational research are areas of particular interest to the organisers of MGs and the decision makers for public health, especially those in poorly resourced countries. The modern day idea of MG health has developed from the notion that “mass gatherings

medicine is concerned with the provision of emergency medical care at organized events with >1000 people in attendance”¹⁸ to include several specialties (figure). The intricate interactions between the different specialties is essential for the planning and success of MGs. New advances or interventions undertaken in other specialties should be integrated with research into MGs.

The proposed research agenda is a broad strategy for research into public health, with a focus on issues related to MGs. It is not intended to be an exhaustive compilation of all possible research questions about the strategic planning for and operation of MGs. Instead the agenda is an outline of key research into methods to control public health and policy. The results of this research can provide an evidence-based platform for policy decisions and practices to reduce the risks and effects of MG-associated health issues and global security risks to public health.

The principal objectives of this research agenda are to identify topics for research and underpin and prioritise their importance in achieving interventions for the control of public health; provide a research framework to gather evidence to address health issues associated with MGs and global security risks to public health; ensure focus on less well addressed issues such as operational and implementation research, particularly for under-resourced regions; provide a platform to enable coordination, discussion, and interaction among organisers of MGs, public health professionals, and researchers; and encourage a multidisciplinary approach to address gaps in knowledge about health risks associated with MGs and their control.

The proposed research agenda is organised as a framework of five major public health research directions.

Reducing risk of public health emergencies

Although many public health emergencies associated with MGs are not predictable, much can be done to prevent and minimise their effects. Continuous monitoring of participants’ vulnerability to health risks at MGs and understanding trends in risks that are associated with specific events (religious, sports, or concerts) can be used to predict what might happen in the future. They are also essential for successful preparedness and management of risk reduction and strengthening the response capacity of host and home communities. Recognition and analysis of the changing risks and vulnerabilities during MGs are starting points for raising awareness and communication of pending risks. Building global capacity for health intelligence for non-communicable and infectious diseases is important for the elucidation of the risks associated with MGs. Most of this information is available through networks such as the emerging infectious disease networks^{19,20} and the WHO Global Noncommunicable Disease Network.²¹ Importantly, the information can be used to implement strategies for risk assessment and mitigation in planning for specific MGs (panels 1, 2).

Panel 1: Agenda for public health emergencies

Development of integrated global health information capability

Global clinical and laboratory surveillance systems for communicable diseases, such as those for seasonal and pandemic influenza,²² are well established. The establishment of country-level surveillance systems for infectious diseases that can be adapted to different epidemiological settings for mass gatherings (MGs) could also provide alerts for the occurrence of non-communicable diseases, such as radiation-related or chemical-related illnesses or those caused by extreme environmental temperatures (eg, Program for Monitoring Emerging Diseases).²³ An important component of the alert and response strategy is an integrated event management system that provides a platform for rapid dissemination of devices and procedures required for the management of health risks. Research into their development and implementation is needed. Syndromic surveillance can potentially provide rapid initial information about the occurrence of both non-communicable and infectious diseases. However, its establishment and assessment of effectiveness during MGs might require further assessment. Further work is also needed to identify appropriate parameters for assessment of the effectiveness of such surveillance systems during MGs.

Enhancement of surveillance activities

Surveillance of non-communicable diseases is a formidable but necessary step for the improvement of the health of the global community. An estimated 63% of global mortality in 2008 was attributable to non-communicable diseases and 80% of such deaths occurred in low-income and middle-income countries.²⁴ Age-specific and sex-specific profiles of non-communicable diseases by country²⁵ allow host countries of MGs to estimate possible risks of non-communicable diseases in participants from specific countries and plan for mitigation strategies.

Although the challenges for the organisers of MGs and the effects of infectious diseases at such events have been summarised,^{6,14} there are many gaps in our understanding of emerging communicable diseases. Integration of information from local and international surveillance of infectious diseases is important for strengthening the intelligence about the global threats before, during, and after MGs.²³

Assessment of risk

The risks of non-communicable and infectious diseases during MGs are proportional to the probability of occurrence of risk factors during the event. The identification of these risks factors

for the different types of MGs will provide a scientific basis for planning effective prevention. Although major risk factors associated with non-communicable and communicable diseases are likely to be similar worldwide, factors specific to the type of MG might lead to health problems. Systematic risk assessment helps identify potential risks of outbreaks and guides the establishment of effective risk management solutions. Systematic assessment will also identify potential or deliberate health security risks that require assistance from other authorities and government agencies.

The leading causes of morbidity and mortality during the Hajj are heat-related illnesses and trauma-related injuries. Identification of such risks allowed event planners to instigate preventive measures and rapid response strategies. Provision of shaded areas can reduce the incidence of heat-related illnesses and effective crowd control reduces the risk of a stampede. Drug and alcohol use were identified as health risks for other types of MGs;²⁶ therefore, restriction of their use can mitigate the associated illnesses. The types and magnitude of health risks associated with spontaneous MGs due to natural disasters and conflicts are different from those of organised MGs. Objectives for risk management at such events are focused on facility-based health-care provision in addition to prevention.

The potential for importation and subsequent global spread of infectious diseases during MGs are well understood. Many emerging human infections are recognised as zoonotic diseases (eg, severe acute respiratory syndrome [SARS], influenza A H5N1, Nipah virus infection). The emergence of novel or rare pathogens in home communities and their subsequent spread to the host community and beyond can be amplified during MGs.

Planning for MGs and public health legacy development

Planning for the potential risks and hazards that are associated with MGs is essential to ensure success. Many reports and manuals are available for planning MGs;^{1,27-32} however, their use should be tempered by the results of the risk assessment. Importantly, planning should maximise the legacy of the MG. The conceptual model of a lasting public health legacy as a framework for the relation between planning inputs, implementation, and public health outcomes was put forward by WHO and the International Olympic Committee to ensure sustainable, positive health effects for the host communities after the Olympic Games.¹¹ Legacy planning should also include passing the knowledge gained to future hosts of similar MGs.

For Program for Monitoring Emerging Diseases see <http://www.promedmail.org/>

Non-communicable and communicable diseases

Morbidity and mortality at MGs can be mitigated through the assessment and management of risks associated with pre-existing non-communicable diseases. Mitigation methods such as the provision of essential drugs and information about their availability at the MG can be initiated during pretravel medical care and advice.^{5,26} Incidence of trauma and heat-related illness at a site can

be reduced with the provision of advice and installations to combat the effects of weather, and effective crowd control.⁵ Models for the prediction of the spread of infections and occurrence of other emergency health issues during MGs have yet to be validated.⁷

Many of the difficulties in restricting the spread of emerging communicable diseases^{6-8,23} are not new and have proven difficult to resolve. There is also uncertainty

Panel 2: Research topics for public health emergencies**Integrated global health information capability**

- Assessment of syndromic surveillance for mass gatherings (MGs) and its applicability in early alert and response systems
- Development of methods to integrate global surveillance intelligence for non-communicable and infectious diseases into the planning for MGs
- Development and implementation of event management systems that integrate information for global surveillance and allow immediate mitigation of non-communicable and infectious diseases

Enhancement of surveillance activities

- Continued assessment of population trends of non-communicable diseases related to MGs, particularly in low-income and middle-income countries
- Investigate environmental, host (intermediate hosts and people), and pathogen-specific factors with the potential to spread (eg, infectivity, transmissibility, and pathogenicity) communicable diseases, particularly in relation to MGs
- Promote a multidisciplinary approach for the establishment and integration of effective surveillance systems for existing and emerging infectious diseases in relation to home and host populations during MGs
- Develop clinical and laboratory algorithms for differential diagnosis of infectious diseases caused by rare and emerging pathogens to aid surveillance and alert efforts
- Operational research to establish social, political, economic, and legal strategies for reporting infectious diseases (eg, International Health Regulations)

Assessment of risk*Non-communicable diseases*

- Development of standardised terms and definitions for the description of health risks associated with non-communicable diseases that are specific to MGs
- Research and promote the development of multidisciplinary and integrated risk assessment systems (eg, environmental factors, transport patterns, crowd psychology, and availability of health services) for existing and perceived health issues related to the specific type of MG for host and home communities

Infectious diseases

- Development of methods for risk assessment in association with global surveillance for mapping indigenous versus potentially imported infectious pathogens
- Develop criteria for proceeding with, restricting, modifying, postponing, or cancelling the event based on a thorough risk assessment
- Investigate human behavioural factors associated with acquiring infections (including zoonosis) and spread during MGs
- Identification of genetic or other factors related to human susceptibility to infection with emerging pathogens
- Potential modes of transmission of infections with emerging pathogens among people at the MG

Planning for MGs and public health legacy development

- Share experience gained from various types of MGs
- Develop criteria for measuring legacy and long-term successes for different types of MGs
- Analyse long-term effects of legacies of global health and security

about how observations pertaining to particular pathogens, population groups, or settings can be used to develop public health policies for planning different types of MGs. The development of evidence-based strategies for non-pharmaceutical interventions is urgently needed to address infection control and mitigate spread in the absence of available drugs and vaccines. Additionally,

such strategies are of particular concern for countries that do not have adequate access to pharmaceutical interventions such as vaccines and antimicrobial drugs. In some instances, available data for planning MGs might not have been assimilated in the best way for policy. A balance between basic scientific research and operational research is essential to inform the implementation of prevention strategies, best practices, and public health decision making (panel 3). Research into how to contain the spread of infectious diseases should have the broadest possible applicability in different settings and at different resource levels. However, some results might not be generalisable to the planning for MGs, such as those from studies of pathogen transmission in health-care settings.

Management of health risks

Effective management of health risks for non-communicable and infectious diseases during MGs requires planning in advance. It is an integral part of planning that consists of risk identification, communication, analysis, assessment, prevention, and monitoring.^{23,28,29} Many of the processes for risk management of non-communicable and infectious diseases during MGs are common. However, each can be specific to the type of MG and needs to be addressed accordingly.^{8,26} High visibility of MGs complicates risk management and can lead to political and media pressure and thereby affect the decision-making process.

Development of preventive measures

Prevention of the occurrence of non-communicable and infectious disease at MGs requires coordinated risk assessment and management before, during, and after the event as shown in the planning for the Hajj.^{2-6,26} Ideally, the primary prevention of human infections with emerging communicable diseases is the effective control of pathogens at their source. Since at-source elimination of all emerging pathogens is not possible, secondary interventions (eg, pharmaceutical or non-pharmaceutical) are needed to mitigate the spread of infection during MGs. However, the effectiveness of such interventions has not been established.^{33,34} In addition to reduction of the rates of morbidity and mortality associated with human infections during MGs, reduction of both the circulation of pathogens and human exposure might lessen the global health security risks.

Minimising effects of public health events

The effect of emergencies and crises on health can be substantially reduced if home and host communities are well prepared and are able to reduce their risks. The main challenge during MGs is the existence of systematic operative capacities such as risk assessment plans, coordinating mechanisms and standard procedures, institutional capacities, legislation and budgets, skilled

Panel 3: Research topics for non-communicable and infectious diseases

Health risks

- Develop and assess models for integrated risk management of multidisciplinary command and control for local and international mass gatherings (MGs)
- Develop and monitor global MG-specific integrated surveillance and alert systems for emerging infectious diseases to monitor circulation of novel or rare pathogens in host and home countries with varying capacity and resources
- Establish effective procedures for emergency response, quarantine of infected individuals, and tracing contacts (local and international), and assess long-term effect on global public health

Prevention

- Assess the dynamics of spread in different epidemiological settings (eg, rural vs urban, tropical vs temperate climates) and the implication of global spread
- Study the interaction between pathogens and their effects on transmission and severity of illness (eg, secondary infections)
- Study the application and timing of response strategies—including containment and border control policies—during early phases of spread
- Study the dynamics of transmission of infectious diseases that are associated with MGs in different epidemiological settings and the factors that affect infectivity
- Assess the role of host factors such as age, pre-existing immunity, antimicrobial treatment and prophylaxis, and vaccination in modulating pathogen transmission during MGs
- Study the stability of different microbial pathogens on various environmental surfaces and under different conditions (eg, humidity, temperature, and presence of organic matter) and their relevance in transmission
- Compare the different types of non-pharmaceutical interventions and study the effectiveness, cost-effectiveness, and feasibility at the individual level such as hand hygiene, masks, and respirators in preventing infection in various epidemiological settings associated with MGs
- Study the effectiveness, cost-effectiveness, and feasibility of interventions at the community level such as tracing contacts and quarantine, closure or restricting activities of MGs, and environmental control methods such as ultraviolet-light filters, air circulation, and natural ventilation on reducing infection
- Selection, timing, and optimum implementation of individual and community public health interventions that are most relevant to event planning

personnel, information, and public awareness and participation that can reduce public health effects and economic losses. Panel 4 shows the suggested topics for research.

Panel 4: Research into minimising the effects of public health events

Public health policy for mass gatherings (MGs)

- Develop generic guidelines for policies to address the health issues that might arise during spontaneous MGs
- Assess existing and new policies and strategies to optimise vaccine uptake and improve vaccine acceptability in the planning for MGs
- Establish criteria and mechanisms to assess the immediate-term and long-term effectiveness or cost-effectiveness of health policies established for MGs
- Assess the effectiveness of policies for immunisation in conjunction with other non-pharmaceutical interventions
- Study the role of research in social science—eg, in establishing social, ethical, and legal standards in the application of public health policy for MGs

Vaccines for infections at MGs

- Enhance applications of existing vaccines against possible infectious diseases that are associated with MGs
- Assess the global vaccine supply and production to improve the processes of rapid response, surge in capacity, and rapid deployment and tracking of vaccine use for planning MGs
- Develop innovative clinical trial methods to study the effectiveness and safety of novel vaccines before and after licensing
- Develop new vaccines, platforms, and formulations that are safe with enhanced immunogenicity, especially in children and elderly people

Vaccination is highly effective in the prevention of infectious diseases. However, many countries, particularly those with insufficient resources, have not developed strategies for vaccinating their populations at risk and people travelling to MGs. The reason is partly related to the lack of information about the transmission of infectious diseases (eg, influenza) and the social, economic, and health effects to the host and home communities. Public health authorities need to decide how to effectively prioritise vaccine use on the basis of available information about disease burden and severity, epidemiology, and vaccine effectiveness and safety for vaccine-preventable infections associated with MGs.⁶ A failure to promote and implement the polio vaccination programme caused the re-emergence of poliovirus in Nigeria and subsequent international spread,^{35,36} emphasising the risks associated with insufficient vaccine coverage for participants at MGs. An outbreak of *Neisseria meningitidis* serogroup A (originating from Africa) during the Hajj in 1987³⁷ was later successfully controlled with the introduction of mandatory pretravel vaccination and use of fluoroquinolones among African pilgrims.³⁸ However, there are infectious diseases, including some of the most important and most dangerous, for which there are no vaccines.

Development of public health policy

Risk assessment and management during the planning for MGs can enable the development of effective health policies. Strategic risk assessments are used to gather, coordinate, and analyse data that are necessary to identify existing risks, anticipate potential difficulties, establish

Panel 5: Research topics for medical services and treatment**Pathogenesis and clinical severity**

- Investigate the role of microbial factors (including replication sites and duration and pathogen load levels) and innate and adaptive immune and other host responses in the severity of disease and associated complications
- Define the clinical spectrum and natural history of infectious diseases associated with MGs, including risk factors (such as demographic factors) and prognostic markers for severe disease and complications arising from such a disease
- Study the role of pre-existing infections (eg, *Mycobacterium tuberculosis*, HIV) and other comorbidities (eg, chronic illnesses) in the severity of infectious diseases
- Study the role of host genetic factors on susceptibility and severity of infection

Clinical management of patients

- Develop rapid, reliable, affordable point-of-care diagnostic tests for various infectious diseases
- Identify clinical markers and develop point-of-care protocols for the prognosis and management of infections
- Optimise the effectiveness of existing and novel treatments through the development of new formulations, delivery routes or systems, and synergistic drug combinations
- Develop novel and effective treatment strategies including adjunctive treatments (eg, immunomodulator drugs, immunoglobulins, and natural products) that are applicable in low-resource areas and in field conditions (such as availability, whether licensed or not, acceptance, and efficacy in different ethnic, sex, and age groups) and are easy to administer in paediatric-care and emergency-care settings
- Optimise management of people who are at risk of severe disease and complications, including emergency-care practices that are applicable across a range of resource settings

Health-care capacity and response

- Assess the effectiveness of global, national, and local responses to outbreaks of communicable diseases and develop new methods for assessment
- Undertake operational studies to investigate the surge capacity needs, particularly in host countries for MGs, including development of triage schemes in different health-care and resource settings, and surge planning to maintain adequate resources
- Undertake studies to identify evidence-driven clinical-care pathways and principles that optimise health-care delivery in a range of resource settings
- Undertake studies to develop principles and practices for rapid assessment and introduction of new interventions during health emergencies, including systems for collation, sharing, and assessment in real time of clinical data

priorities, and provide the basis for enacting targeted policies and implementation of corrective interventions. A system is needed for the measurement of the effect of public health policy and estimation of the probability of success. These interlinking processes are well described for regularly organised events such as the Hajj and Olympic Games.^{5,11,14} An example of the effective development of health policy is the organisation of the Hajj—such as a smoke-free environment for the prevention of fire, structural changes to prevent crowding, and recommendations for vaccination of pilgrims to prevent transmission of infectious diseases (eg, influenza, meningitis, poliomyelitis).⁵ However, such effective policies are not possible for spontaneous MGs such as population displacement as a result of natural disasters or conflicts.

Vaccine research

Development of vaccines for emerging infectious diseases presents substantial challenges and can take many years for diseases that are caused by novel pathogens such as severe acute respiratory syndrome (SARS; panel 4). Even if a vaccine exists, it might need to be regularly updated, clinically assessed for safety and efficacy, and promptly produced for immediate use (eg, influenza vaccines). The efficacy and effectiveness of a vaccine are dependent on the immune responses that are determined by the age of the recipient and composition of the vaccine (eg, conjugated or adjuvanted). Improvements to vaccines and formulations that can provide longer-lasting and broader activity afford better protection, increase the applicability of vaccines, and reduce the frequency of vaccination. During an outbreak, the important factors are the rapid production and equitable distribution of vaccines to countries in need.

Medical services and treatment of diseases

Ensuring rapid and effective management of patients and prevention of diseases requires robust health services at MGs. Providers of emergency services play an important part in ensuring public safety during such events. Knowledge and monitoring of medical service provision during MGs has been rapidly increasing in the past decade.^{12,13,39} However, a lack of consolidated data for different types of MGs means that organisers are not able to plan accordingly for the emergency medical services that might be needed. Improved and targeted clinical management and infection control can substantially reduce the incidence and transmission of infectious diseases during MGs. Optimum clinical management must be based on an improved understanding of the pathogenesis of these infections, advances in laboratory diagnosis, development and application of effective antimicrobial drugs, and other treatment modalities (panel 5).

Pathogenesis and clinical severity

There are many gaps in our basic understanding of how many of the pathogens that are associated with MGs cause disease in people and what factors affect severity of illness. Host immune responses, underlying comorbidity, age, and the properties of the infecting pathogen can all contribute to severity.

Clinical management of patients

The clinical presentation of many infections, such as influenza, is not specific, which makes differential diagnosis and early treatment to reduce further transmission and severe outcomes difficult. For example, antibiotics can help control severity and further spread of travellers' diarrhoea caused by bacteria. Rapid and reliable diagnostic testing can expedite the initiation of timely and appropriate treatment and infection control. Increase in and optimisation of the repertoire of antimicrobial drugs

and development of clinical research to assess efficacy of putative adjuvant treatments such as immunomodulator drugs, passive immunotherapy, and traditional medicine that are suitable for use in under-resourced areas would be most beneficial in the preparation for MGs (panel 5).

Health-care capacity and response

The availability and quality of health services contributes to the effect of infectious diseases in the source and home countries (panel 5). The same pathogen that might have a small effect on the rates of morbidity and mortality in countries with well organised health-care systems can be devastating in countries where health-care systems are suboptimum.

Development and application of modern public health methods

New public health methods need to be harnessed to help reduce the effect of health problems during MGs. Use of innovative communication channels, such as the internet and mobile phone networks, have the potential to aid surveillance, rapid risk assessment, and dissemination of accurate information.^{23,40,41} Mathematical modelling and risk communication have potential applicability in all aspects of research into health risks associated with MGs.

Modern methods for early detection and monitoring of disease

Some countries and MG organisers use state-of-the-art approaches for early detection and monitoring of diseases such as syndromic surveillance.^{3,29} In some countries computerised health-care and laboratory-based information systems are used for planning MGs and these systems can be adapted for monitoring large-scale outbreaks. Other innovative technologies such as mobile phones can be used in remote areas or countries that lack the resources to gather and transmit health-related data in real time, provide rapid feedback, and train health-care workers.^{7,23} Applicability and use of these modern methods of monitoring in different settings and contexts require further investigation, with special attention to issues related to integration and interoperability of initiatives for infection control during MGs (panel 6).

Role of modelling in public health decision making

Evidence-based public health decision making in planning and mitigating health risks requires rapid access to information. However, such information is often incomplete, evolving, and derived from an increasingly complex array of sources such as basic science researchers, epidemiologists, social and political scientists, and economists. Modelling is useful in that it can incorporate diverse data to inform public health policy and decision making.^{42,43} Advances in mathematical modelling for public health are expected to include computational structural biology; integration of epidemiological and geographical data into phylogenetic models; within-host

Panel 6: Development and application of modern public health methods

Research in early detection and monitoring of disease

- Identify, develop, and adapt modern technologies for early detection of outbreaks of communicable diseases and their application in disease surveillance during MGs
- Integrate and continuously assess innovative approaches and channels for disease surveillance and monitoring
- Develop efficient mechanisms to address the global challenges to sharing information, data, and details about pathogens identified during outbreaks at MGs in terms of local, ethical, legal, and research perspectives
- Define the timeliness and quality of data required for early detection of disease from local to district, regional, national, and global levels

Research in modelling public health decision making

- Assess the application of modelling to understand and estimate key parameters for risk management
- Investigate the role of modelling to assess effect of public health policies for different MGs
- Assess modelling in public health policy planning and strategic decision making in MG planning

Research in strategic and risk communication

- Measure the role and effectiveness of different communication channels and formats for different target audiences for MGs
- Assess the effectiveness of different forms of social networking in MG planning and operation
- Assess the social, economic, cultural, and religious factors in risk perception and behaviour change in different settings for MGs
- Assess factors that contribute to trust among the general population and in different settings for MGs
- Investigate the best way to communicate uncertainty and the responses of different groups
- Assess multicomponent communication interventions to promote preventive methods

and population-level susceptibility models; behavioural modelling; and assessment of the effects of climate change on disease transmission and the use of novel datasets on contact patterns and population mobility.^{44–48}

Modern methods for strategic and risk communication

Communication is a key strategy in risk management in planning for MGs. The SARS outbreak in 2003 reinforced the idea that a timely and transparent public information policy could help reduce excessive and inappropriate public health responses and minimise the social disruption and economic consequences of a fast-moving global epidemic.^{49,50} Increased investment in identifying effective approaches and developing and assessing new communication methods will benefit risk prevention and control efforts. The specific challenge is to provide clear, credible, and appropriate communication to meet the needs of diverse communities and retain public trust in a dynamic yet unknown process.^{51,52} Some of the main research topics in this specialty include the link between communication and behaviour change models; development and assessment of methods that can be quickly accessed and used in MGs; and assessment of best practices, challenges, and barriers in risk

Search strategy and selection criteria

We identified references for this review by searching PubMed, Medline, and the internet for articles published in English from January, 1960, to June, 2011, by using the search terms "mass gatherings", "research", "infectious diseases", "communicable diseases", "non-communicable diseases", "public health", "alert and response", "mass gatherings planning", "legacy", "outbreak", "surveillance", "prevention", "treatment", "Olympic games", and "Hajj". We reviewed the articles and information found during these searches. Additional references cited in the articles were also reviewed.

communication from previous examples (eg, the 2009 influenza A H1N1 pandemic).⁵³

Conclusions

Research into health issues related to MGs is at an early stage. Research directions outlined here should contribute to the evidence that can be used to formulate risk management guidelines and assist event planning and health-care policy makers. The research agenda presented here is not intended to be restricted to specific aspects of health research but rather to encourage a multidisciplinary approach focused on MG health and to help gain more knowledge. In the future, the focus should be on strategies directed towards developing common research frameworks and definitions. Additionally, the knowledge generated by use of the multidisciplinary approach to research ought to be assessed for direct relevance to MGs in terms of their capacity for integration in legacy building and systemic sharing of information.

Contributors

JST wrote the text. MB planned the outline for the review, and provided and consolidated WHO policies and guidelines about MGs. ZAM provided the concept for the review and planned the content with the team. NS provided the outline and wrote the section about risk communication. SB provided information about outbreak control and research agenda for influenza. M-PK contributed information about health research directions and vaccine development. All authors reviewed and provided advice on drafting the review.

Conflicts of interest

We declare that we have no conflicts of interests.

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