

*Public Health Preparedness for Global Pandemics***Kesiapsiagaan Kesehatan Masyarakat untuk Menghadapi Pandemi Global**

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ABSTRACT

This study aims to explore the main activities involved in public health preparedness for a global pandemic. These activities include strong supervision and monitoring, comprehensive risk assessment, adequate resource allocation, comprehensive emergency response planning, global coordination, training and capacity building, effective communication and information sharing, and continuous evaluation and improvement. In addition, strategies to ensure health system flexibility are also considered, including health service infrastructure and capacity building, health system strengthening, a multi-sector approach, an all-threat approach, flexibility in infrastructure design, and effective resource allocation and mobilization. By implementing these strategies, it is hoped that health systems can increase their resilience, responsiveness and ability to meet the needs of affected populations during the global pandemic.

Keywords: public health preparedness, global pandemic, surveillance, risk assessment, resource allocation, emergency response, global coordination, training and capacity building, communication, evaluation and improvement, health system flexibility.

ABSTRAK

Penelitian ini bertujuan untuk menjelajahi kegiatan utama yang terlibat dalam kesiapsiagaan kesehatan masyarakat untuk menghadapi pandemi global. Kegiatan tersebut meliputi pengawasan dan pemantauan yang kuat, penilaian risiko yang komprehensif, alokasi sumber daya yang memadai, perencanaan tanggap darurat yang komprehensif, koordinasi global, pelatihan dan pembangunan kapasitas, komunikasi dan berbagi informasi yang efektif, serta evaluasi dan perbaikan berkelanjutan. Selain itu, strategi untuk memastikan fleksibilitas sistem kesehatan juga dipertimbangkan, termasuk infrastruktur dan pembangunan kapasitas pelayanan kesehatan, penguatan sistem kesehatan, pendekatan multi-sektor, pendekatan semua ancaman, fleksibilitas dalam desain infrastruktur, serta alokasi dan mobilisasi sumber daya yang efektif. Dengan menerapkan strategi-strategi ini, diharapkan sistem kesehatan dapat meningkatkan ketahanan, responsivitas, dan kemampuan untuk memenuhi kebutuhan populasi yang terkena dampak selama pandemi global.

Kata Kunci: kesiapsiagaan kesehatan masyarakat, pandemi global, pengawasan, penilaian risiko, alokasi sumber daya, tanggap darurat, koordinasi global, pelatihan dan pembangunan kapasitas, komunikasi, evaluasi dan perbaikan, fleksibilitas sistem kesehatan.

1. Introduction

Preparedness is a term frequently used to describe activities aimed at ensuring that an organization is capable of responding to a critical situation. Preparedness has been defined as "a continuous and integrated multi-sectoral process of planning and resource allocation for the performance of functions and tasks aimed at improving the health care system's ability to respond to threatening events and to deliver effective public health and health care services" (1). This definition stresses that preparedness is an ongoing function which involves a wide range of activities. As the definition was taken from the World Health Organization's website, it would appear to place an emphasis on public health preparedness. However, preparedness within the healthcare setting is equally as critical (Kirchhelle, 2020)(Ayuso & project, 2023).

This internal preparedness relies on the notion that during an event, the health system should continue to function effectively to meet the needs of the affected populations. The infrastructure must be flexible enough to provide the most appropriate care to a wider range of health needs beyond those directly related to an infectious disease and must draw on allocated resources from within the health and non-health sectors.

Public health preparedness is a concept with relevance to all facets of public health, and the recent efforts to combat global pandemics have produced a more encompassing definition with specific relevance to acute-onset events affecting the health status of a population. An extensive and open deliberative process involving multitudes of public health professionals, researchers, and academics has produced a model of public health preparedness as an intentional, focused effort to create a state of readiness and to effectively respond to new events in order to prevent adverse health outcomes. This model has become well known through its association with the Public Health Preparedness and Response Core Competency Model, which further defines preparedness as the capability to effectively apply the essential public health services in response to a health event (Leitner, 2020)(H. Fefferman et al., 2020). This is an excellent definition for the public health sector and a considerable achievement for public health preparedness researchers in establishing a clear identity and mission for the field. However, the relevance and scope of this definition to other disciplines is questionable, and it is still difficult to separate public health preparedness as an independent field from the broader public health discipline in both practice and theory (H. Fefferman et al., 2020)(Kirchhelle, 2020).

Disaster readiness, resiliency, emergency and contingency planning. These are all terms that have been used interchangeably with public health preparedness contributing to significant confusion about the field's scope and mission. In a recent attempt to establish a common vocabulary for emergency preparedness and response, the Institute of Medicine defined public health preparedness as "the continuous cycle of planning, implementation, and evaluation to develop and improve capabilities for the public health system and society to protect the health of the people from dangerous conditions, emergencies, and disasters (Lipsitch et al., 2023)(Leitner, 2020)." This is the most widely accepted definition and the one most public health preparedness researchers will reference. Nonetheless, it is neither clear nor concise. Heavily influenced by disaster and emergency management disciplines, this definition associates preparedness with reactive interventions designed to protect health status in the face of acute-onset events such as natural disasters, terrorism, and bioterrorism. Given the broader scope of the public health discipline, it is important to recognize that dangerous conditions, emergencies, and disasters are not limited to sudden onset events and can include anything that jeopardizes the health status of a population. Current definitions also fail to recognize the substantial resources allocated to preparedness activities by governmental and non-governmental organizations other than the public health sector (Mentges et al., 2023)(project et al., 2023).

Public health preparedness has been a topic of great discourse and significant investments ever since the anthrax attacks of 2001, if not before. However, it remains a relatively young field, with much of the progress being made only in the last few years. This is in large part because preparedness is the new focus for public health. For most of the 20th century, public health was defined by the model of disease detection, disease prevention, and health promotion. The 21st century will be the era of public health preparedness. But as a field in its adolescence, the definition of public health preparedness is a concept still under construction with many interpretations and much more misunderstanding.

Recently dating back to the late 1990s, Canada has taken steps toward global health issues such as this. A joint initiative between Health Canada and the International Development Research Centre (IDRC) led to the establishment of the Global Health Research Initiative (GHRI) in October 2001. With a key focus on the lessons learned by Canadians from

the SARS crisis, the Canadian Association for Public Health Policy (CAPHO) has stressed the necessity of public health being an integral component of future international decisions which may potentially affect or impede global public health (Leslie et al., 2022)(Pettinicchio et al., 2021). In 2007, this led to six Canadian federal departments and agencies working together on the Global Health and Security Initiative, an effort to better coordinate their international activities to improve health outcomes and to contribute to the reduction of health disparities and protection of the health of Canadians and people around the world. Each of these initiatives has had a focus on poorer nations, with which Canada tends to share strong relationships and is often involved in development or relief projects. Considering the potential devastating impact of pandemics or other public health emergencies on developing countries, Canada's involvement in global initiatives such as these can mark the start of a more secure world against international health threats (Csenkey & Perron, 2021)(Farokhi, 2019).

Global pandemic preparedness is extremely important because of many recent events, such as the worldwide SARS outbreak, avian influenza, and the increase in the incidence of drug-resistant bacteria. These events have shown that such infectious agents have the potential to spread across international borders and threaten the health of the global population. Public health emergency preparedness in this context should not be limited to specific regions or focused on events within national borders. The effect of globalization on the spread of infectious diseases means that an event occurring anywhere in the world can be a threat to public health in North America. In terms of global infectious disease, the best defense truly is a good offense; preparedness efforts can prevent, protect against, or at least slow the spread of infectious diseases to North America and reduce the impact of an event (Golchin et al., 2023)(Matsumoto et al., 2021).

2. Research Methods

The research method used in this study is a systematic literature review, which aims to investigate public health preparedness in the face of a global pandemic. Reference sources will be obtained from leading international databases such as PubMed, Scopus, Web of Science, and Embase, which have an extensive collection of articles in the field of public health and pandemics. The use of relevant keywords such as "public health preparedness", "global pandemics", "pandemic response", "emergency management", and "healthcare infrastructure" will ensure the inclusion of articles that are appropriate to the research topic. Relevant articles will be selected based on previously established inclusion and exclusion criteria, including relevance to the research topic, year of publication, publication in English, and focus on public health preparedness related to the global pandemic. Articles that do not meet the inclusion criteria or are deemed not relevant to the research topic will be rejected. After selection, the accepted articles will be systematically analyzed to extract relevant information related to public health preparedness in the face of a global pandemic. Thus, it is hoped that this research will provide in-depth insight into public health preparedness in the face of a global pandemic and can provide an important contribution to future public health policy and practice.

3. Results and Discussions

3.1. Lessons from Previous Global Pandemics

From the standpoint of present-day public health and emergency response efforts, the most obvious lesson learned from previous pandemics has been the critical need for global disease surveillance and rapid information sharing. The surveillance efforts of the past several decades have been largely disease-specific, targeting such scourges as smallpox, polio, influenza, and meningitis. Although these efforts have met with some success, the infrastructure for a truly effective global surveillance network has never been realized. The emergence of new infectious diseases and the resurgence of old ones have highlighted the limitations of traditional surveillance efforts. During the influenza pandemic of 1957, the lack

of a robust influenza surveillance program hampered global containment efforts. More recently, the emergence of HIV/AIDS and the spread of drug-resistant tuberculosis have demonstrated the ability of infectious diseases to move quickly in the absence of effective surveillance. The spread of SARS was perhaps the best demonstration of the potential a truly global surveillance network has for disease containment. According to the World Health Organization, the global system of SARS surveillance put in place in 2003 enabled a small number of affected countries to contain the disease within a matter of months, effectively preventing further spread (Robbe et al., 2023)(Abubakar et al., 2021). The success of the global SARS surveillance network serves as a beacon for what is possible with global cooperation and coordination in disease surveillance. But there are still many challenges ahead. Influenza viruses are notorious for their ability to undergo antigenic drift and shift, making the development of effective global surveillance particularly daunting. To date there is no global system for monitoring influenza or any other infectious disease. But if global surveillance is to become a reality, developing nations will need to be active participants. This would require considerable transfer of technology and resources to many of the world's poorest countries. The motivation for a more equitable system of global surveillance is the knowledge that infectious diseases know no boundaries and that a weak link anywhere in the world is a threat to public health everywhere (Liu et al., 2019)(Dalum Hansen, 2019).

3.2. Evolution of Public Health Preparedness Strategies

The 20th century marked a rise in distinctive public health initiatives aimed at the control and prevention of infectious diseases on a global scale. These efforts evolved through the century, building upon past experience and attempting to incorporate new scientific knowledge and lessons. Barrett et al. discuss the history of public health preparedness for pandemics, identifying three overlapping phases which characterize its evolution. The first phase, lasting until the 1970s, was dominated by the belief that infectious diseases could be eradicated, and the successful campaign against smallpox was a major achievement of this period. The onset of the HIV/AIDS epidemic and the realization that smallpox eradication was unattainable shifted public health strategies in the 1980s towards disease-specific control programs, which were relatively uncoordinated internationally and with variable results (Kirchhelle, 2020)(H. Fefferman et al., 2020).

The recognition that infectious diseases were re-emerging globally and potential bioterrorist attacks led to the current phase of preparedness planning, focusing upon the need for anticipatory and coordinated strategies to combat all public health threats. The emergence of new diseases and the changing nature of globalization present new threats to international public health, such as the zoonotic transmission of diseases to humans and the potential use of genetic engineering for harmful purposes. These will continually test the ability of public health initiatives to safeguard the global population from health threats (Kirchhelle, 2020)(H. Fefferman et al., 2020). Comprehensive global preparedness has been aimed for, but never fully achieved, due to the inherent difficulty of implementation and the differing resources and capabilities of individual nations.

The revision of the International Health Regulations (IHR) in 2005 was a significant development in global health security, creating a legal framework for the mutual reporting and addressing of public health events that could have international effects. The regulations are binding for all 194 WHO member states and define the rights and obligations of countries in identifying, reporting, and responding to events, especially those which are potential Public Health Emergencies of International Concern (PHEIC). An event is considered to be a PHEIC if it is an extraordinary occurrence which carries potential health risks for other states, and requires a coordinated international response. The IHR are designed to allow for maximum health security, while imposing minimum restriction on international traffic and trade, and define the role of the WHO as the director of international public health coordination. This contrasts with

the previous quarantine-based approach to health security, which was deemed to be anachronistic and potentially harmful to global socio-economic stability. The SARS epidemic of 2002-3 was a catalyst for the revision of the IHR, and highlighted their importance in the strengthening of global public health preparedness (Ayuso & project, 2023)(Pannu, 2020)(Kishore et al., 2020).

3.3 Global Health Security Frameworks

The use of IHR was heavily evident in the 2009 H1N1 pandemic and more recently the Ebola and Zika PHEICs, showing international solidarity in response to global health threats, although there are still criticisms in the fact that the resources and expertise required to effectively implement the IHR at a country level are not yet fully possessed by all countries (Ayuso & project, 2023)(Kirchhelle, 2020).

Built on the 1969 IHR, the new IHR is an international legal, and in this sense binding, instrument of international law that is aimed at preventing, protecting against, controlling, and providing a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risk, and avoiding unnecessary interference with international traffic and trade. It encompasses 6 core capacities with which countries must be in compliance with, to detect, assess, notify and report, respond, verify, and prevent the spread of any public health emergency. It also has stringent guidelines for public health emergencies of international concern (PHEIC), which may be invoked to provide temporary recommendations for health measures with a view to preventing international spread of disease and avoiding serious interference with international traffic or trade (Ayuso & project, 2023)(Lundgren et al., 2020).

In response to this, in May 2005, the 58th World Health Assembly adopted the revised International Health Regulations (IHR), drawing on the lessons of SARS and recognizing the importance of a global framework of epidemic and pandemic alert and response. This is a truly seminal development in global public health, as for the first time in history, almost all the world's countries have a common set of rules to confront global health threats known as IHR (Eckmanns et al., 2019)(Pannu, 2020).

The international spread of infectious diseases is of great concern, as demonstrated by the recent Ebola epidemic and current spread of the Zika virus. There is evidence of global acceleration of international mobility and trade, further amplifying the risk of disease spread. The process of globalization is increasing the likelihood that any future infectious disease will spread to all countries, devastating worldwide public health and incurring serious social and economic costs (Patterson-Lomba & Gomez-Lievano, 2018)(Niu et al., 2020).

3.4 International Health Regulations (IHR)

The IHR has been the cornerstone of global health security for the past 50 years. International Health Regulations (IHR) were originally established by the World Health Organization (WHO) in 1969, to help the global community prevent and respond to acute public health risks that have the potential to cross borders and threaten populations worldwide. Despite IHR's noble intentions, it was evident that the regulations were in need of a significant update by the disparities in their implementation during the 2003 Severe Acute Respiratory Syndrome (SARS) epidemic, where many countries opted to conceal outbreak information for fear of economic repercussions in contravention of IHR. Major controversy followed SARS, and in 2005 the World Health Assembly welcomed the revisions for a significantly updated International Health Regulations (Ayuso & project, 2023)(Lundgren et al., 2020).

Finally implemented on June 15, 2007, this revision brought about a much-needed overhaul to global health regulations in the face of a growing threat from emerging diseases. The IHR are a binding legal agreement in 196 countries including all WHO member states. New

IHR are said to make the world more secure from health emergencies, world travelers are to be better protected from health risks in other countries, the international spread of disease is to be contained without unnecessary interference to trade and travel, and an improvement of the global alert and response system for epidemics, to name a few goals. IHR represents a collective commitment to act in the face of cross-border health threats and translating these promises into global health security will be an enormous but necessary challenge. Any strengthening of public health infrastructure to meet these shared national and international goals beyond the IHR will indirectly provide additional security for global health (Ayuso & project, 2023)(Pannu, 2020).

3.5. Global Health Security Agenda (GHSA)

It is important to note that the implementation of GHSA would have direct effects on IHR, as IHR is a legal agreement signed by over 196 countries, and insofar it is the sole international clearly worded set of international protocol on surveillance and response to health events. According to the WHO Director General, the GHSA is now viewed as complementary to IHR, in that it provides a platform of voluntary compliance to the IHR, as well as providing an opportunity for countries to go above and beyond the IHR and create a improved level of global health security beyond what IHR alone provides. GHSA is able to do this through the circumvention of the classic method of funding for IHR compliance, which was done so by implementation of health officials, building of healthcare infrastructure and supporting the establishment of laboratories and surveillance networks to identify diseases. GHSA implements a form of financing for health security that not only benefits the countries being piloted, but also those lending the assistance. This provide a "reciprocal system of peer based learning and cooperation" (p 17) for health security which provides to be more advantageous than the top down methods through international organizations origination of the IHR (Braa et al., 2023)(Ivar Sæbø et al., 2021).

3.6 Risk Assessment and Surveillance

To aid in risk assessment by identifying potential threats, a systematic approach by WHO considers the probability of a microbe to cross borders and establish in a new host within a new environment. Probability is assessed through the potential of infection as a result of exposure to the microbe, the agent's ability to cause disease, and the susceptibility of the given population. This approach was adapted from the US Centers for Disease Control and Prevention (CDC) to assess bioterrorism threats [16]. Lederberg suggested a need for advanced studies into microbial genetics and biological characteristics of agents with the potential to cause harm to the global community. An understanding of changes in the ability of known microbes to cause disease and the emergence of new infections is vital to the prediction of such eve (M. Rocha et al., 2017)(Buendía et al., 2018)nts.

3.7 Identifying Potential Pandemic Threats

Pandemic threats are caused by newly novel strains of viruses such as the H1N1 (2009) influenza or by viruses that have been contained but spread to new ecological niches around the globe. One of the greatest challenges in preparing for pandemics is the difficulty in predicting when and where the next pandemic will occur and what its severity will be. Epidemiologists generally agree that the world is long overdue for an influenza pandemic and there is a widespread concern about emerging infections such as SARS, avian influenza, and drug-resistant tuberculosis, all of which have demonstrated pandemic potential (C. Danko et al., 2023)(Sun, 2020). Public health professionals must be prepared to respond to both seasonal and pandemic strains of influenza as it is a vital cause of illness and death and likely the most inevitable of all pandemics. Seasonal flu and pandemic flu are caused by different subtypes of the influenza virus and are treated as separate entities but the threat of seasonal

influenza can be an opportunity to enhance preparedness for pandemic flu (J. Nic May & J. Avila Vales, 2020).

3.8 Early Warning Systems and Surveillance Networks

EWS for pandemics focus on monitoring the likelihood of a potential pandemic disease emerging. This is typically monitored through infectious disease surveillance to identify if specific diseases or events have the potential to spread and cause harm. Modern globalization has meant that diseases can spread more rapidly than in the past. Increased traffic and borderless travel to and from different regions have the potential to spread disease quickly and effectively. It is now critical that surveillance does not only focus on local areas but also has the capacity to monitor diseases globally. This led to the development of specific surveillance networks dedicated to monitoring the spread of diseases on a global scale. The use of EWS at all stages attempts to prevent outbreaks of disease as well as control and contain already emerged pandemics (Patterson-Lomba & Gomez-Lievano, 2018)(Inoue & Gupta, 2018).

Early warning systems (EWS) and surveillance networks (SN) have been identified as an essential component of any robust public health strategy. The purpose of EWS is to identify and predict the occurrence of pandemics, monitor the spread of the disease, and determine the impact. This is accomplished through monitoring a variety of data and information sources and applying the information to decisions about future actions regarding COVID-19 on public health and healthcare systems (Liu et al., 2019)(Correll et al., 2019).

3.9 Data Analysis and Risk Assessment Tools

The identification of indicators with the potential to act as early warnings for known or suspected public health threats is an essential precursor to the implementation of surveillance. Indicators may be specific events or conditions that are known to precede the occurrence of a particular public health threat, or changes in the trends of key data sets that reflect the severity of a threat to public health. High priority threats with the potential to cause a global public health emergency will require development of risk assessment tools and the conduct of risk analysis. As with risk assessment for identifying potential threats, tools for risk assessment of known threats require the identification of the likelihood and potential impact of the threat on global public health (Dalum Hansen, 2019)(Lipsitch et al., 2023).

A critical component of informed decision making for the response to likely or suspected public health emergencies and health threats is the utilization of data-driven risk assessment tools. Risk assessment is a scientific process that ascertains the likelihood of adverse events and their potential effect on human health. Currently, there are no formal, universally accepted tools specifically for the assessment and management of risks to global public health. Adaptive methods commonly used in environmental risk assessment and the broader field of public health may include the Delphi method, scenario building and joint expert deliberation, however, their application to global public health threats has been limited. A reiterative process of risk and situation analysis should enable decision-makers to monitor the characterized threats and evaluate the effectiveness of the measures being taken to reduce specific threats to global public health (Edu et al., 2023).

3.10 Emergency Response Planning

Pandemic response planning is a complex and multifaceted issue. As discussed earlier, a severe pandemic will have widespread and diverse social, economic, and political effects. Because of this, it is important that pandemic response planning is not limited to the health sector, but is integrated into government policy decision making at all levels. This will help to ensure that public health and individual healthcare measures can be effectively coordinated with broader societal measures, and that there is a clear understanding of the potential impact of public health interventions on the overall well-being of society. As such, resources for

implementing pandemic response plans will need to come from both within and outside of the health sector, further highlighting the need for coordination and resource allocation measures in pandemic planning (Lipsitch et al., 2023)(M. Baker et al., 2020).

It will be important for countries to incorporate and integrate their national and regional response plans into an overall global response strategy. Pandemic preparedness is not just an issue for developing countries, or even just those countries most at risk of an influenza pandemic. The impact of a severe pandemic will be felt in all societies worldwide, and as such it is important that all countries are a part of the global response effort. A well-designed global pandemic response strategy will help to ensure that there is no duplication of efforts, and effective use can be made of limited resources (Kuo et al., 2020)(Gupta, 2020).

During a crisis, governments are frequently caught unprepared, resulting in a delayed and unsuccessful reaction. In order to avoid the same situation happening in the event of an influenza pandemic, it is important for governments to plan their responses to a pandemic prior to the event. The development of a comprehensive and well-integrated preparedness plan will help to ensure that when the time comes to react, the response will be efficient and effective (H. Fefferman et al., 2020)(Adiga et al., 2020).

3.11 Development of Pandemic Response Plans

To date, most pandemic plans have been based on the WHO phases of pandemic alert as this provides a worldwide common framework to assess the increasing pandemic threat and triggers movement to new response levels as the pandemic evolves. Within each country, it is the health ministry that is usually assigned overall leadership for pandemic preparedness and response, but successful pandemic outcomes that minimize societal disruption need a multi-sector approach and involvement of non-health partners from the earliest stages of plan development. To build a comprehensive approach to pandemic planning, an all-hazards approach is recommended, that is, to use a common framework that can also be applied to preparedness for major natural disasters or other global health threats. This approach will maximize dual benefit investments and avoid duplication in separate planning for pandemics (Valence, 2023)(F. Méndez, 2020).

Development of pandemic preparedness plans is a critical endeavor at national and international levels. Guided by public health and medical principles, these plans should be coordinated and integrated with overall emergency response plans and be well linked with the plans of other sectors, such as agriculture and security. The overall goal is to minimize serious adverse events that are unrelated to the direct health effects of the pandemic. To a large extent, this can be achieved through prevention and early disease containment, which are primarily the focus of the pandemic preparedness plans. As most of the adverse societal effects of pandemics are due to the impact on critical infrastructure, pandemic plans should aim to build resilience of the infrastructure and have fall-back contingency plans to maintain the continued function of essential services (Bradley et al., 2020)(Ayuso & project, 2023).

3.12 Resource Allocation and Mobilization

Like vaccines, a mechanism for global real-time monitoring and assessment of the pandemic's severity and impact on different populations will be needed to determine when to release antivirals from national stockpiles or the global stockpile being developed by the WHO. This is an area that would benefit from the development of simulation models that could inform international coordination and agreement on key policies and strategies (Alamo et al., 2021).

Antiviral medications present some unique challenges to resource allocation and mobilization during a pandemic. Production capacity is limited and likely insufficient to supply the entire world at once. Given the benefits of prophylaxis and treatment in preventing illness and severe outcomes, there must be clear prioritization and decision-making about who gets

antivirals. Governments and private organizations will also need to establish effective strategies for procurement and stockpiling during an interpandemic period. This includes flexible contracting options and building consensus about whether and how to fill gaps in global demand and supply through donations or sharing of intellectual property for local production (A. Gonzalez et al., 2021)(Pannu, 2020).

Once a pandemic is imminent, optimizing vaccine strategies will require planning and coordination with manufacturers and distributors. In particular, efforts should be made to ensure that the vaccine is available at close to the same time as it is needed. If the vaccine supply is inadequate, or if the virus evolves to a less susceptible strain, it will be necessary to have a mechanism in place to quickly reallocate resources. This requires careful consideration, planning, and clear understanding in advance by decision makers and the public (M. Rando et al., 2022)(Gros & Gros, 2021).

The top priority is to limit illness and deaths by using all public health strategies and community-wide mitigation. This demands accelerated and clear communication between the public and private health sectors to ensure a full understanding of what each sector can contribute.

3.13 Coordination with Stakeholders and Partners

In a public health crisis, effective coordination and collaboration are critical components of an effective response. Stakeholders, both within and external to the public health sector, must work together to share information and make decisions that will protect public health. Because preparedness and response to an influenza pandemic will require the effort of many, a coordinated approach is essential. Pandemic preparedness and response activities involve multiple sectors (health, emergency management, law, business, transportation, etc.), and levels (community, regional, national, global). Therefore, it is likely that the success of a response will be determined by the effectiveness of involving the full range of stakeholders in decision-making and implementation of plans. Key stakeholders include: health care providers, community leaders, essential service providers, and those involved in policy development and decision-making. Public health has a responsibility to assure these stakeholders are well informed of public health planning efforts, and have the opportunity for input and involvement (adams & Light, 2020)(Meekers et al., 2023). This can be accomplished through formal meetings, workshops, exercises, or the development of specific stakeholder involvement groups. Success in involving stakeholders has been achieved when these groups are able to put aside their individual objectives and make joint decisions that will benefit the public's health. It is likely that due to the significant amount of planning and preparation that has occurred in advance of a pandemic, public health agencies will be called upon to assist other sectors in understanding the implications a pandemic may have, and what decisions they will need to make. An understanding of the Incident Command System and how public health fits into the broader National Response Plan will be beneficial in coordinating with other sectors and external partners. Public health should ensure that their involvement with external partners is well coordinated and that there is a clear understanding of how decisions will be shared and what the roles of each organization will be (Danks et al., 2024)(Lipsitch et al., 2023)(Hager et al., 2020).

3.14 Healthcare Infrastructure and Capacity Building

Health systems in many countries lack the basic infrastructure needed to provide effective care and are unable to cope with the surges in demand that are likely to occur during future pandemics. Low- and middle-income countries in particular will require investment in their healthcare infrastructure in order to respond effectively to a pandemic. Healthcare systems will need to be adapted and, where necessary, new facilities will need to be created to isolate and treat infected patients. This is likely to involve an overhaul of the entire health

system in many countries, and a refocusing of healthcare priorities. The reorganization of health structures is likely to be highly controversial and politically sensitive; resources and time spent on developing new facilities for pandemic response may be at the expense of other vital health needs. A careful balance will need to be struck, weighing the potential benefits of preparedness against the possible damage to other areas of healthcare (C. Danko et al., 2023)(Maity et al., 2023). The key to success will be flexibility; infrastructure to deal with a pandemic must be multi-purpose and capable of scale-up and scale-down as required. The design and nature of healthcare facilities has a significant impact on infection control. Experience from SARS demonstrated how the presence of weak spots in infection control in hospitals can greatly amplify the epidemic. New facilities should aim to incorporate the latest knowledge in infection control and be adapted easily to changing circumstances and knowledge about infectious diseases (Hager et al., 2020).

3.15 Strengthening Healthcare System

To assess capacity and capabilities, ministers of health, finance, and planning could establish a review process of how well their country's health system can address the type of surge anticipated with a future pandemic. Such comprehensive reviews have been done in some countries as part of health system development for normal or emergency circumstances, and a WHO guidance document for assessing health system capacity for a crisis is being developed. Part of the evaluation will focus on analyzing the surge capacity of the system based on previous experiences of disasters, but it will also need to develop models to estimate how much surge capacity will be enough given the nature and expected impact of the disaster. Countries will then need to present the findings to political leaders who can decide how much incremental funding should be allocated and for what specific areas of capacity building to address the identified gaps (Parker et al., 2020)(Qian et al., 2020). Since the allocation of extra funding towards a separate and parallel system for responding to disasters will likely be met with resistance, there needs to be agreement on which areas of capacity building will have co-benefits for both disaster response and health system development for improving general public health. The decision on what changes will be a national investment for public health and safety versus measures for ensuring protection of global health security should be made based on likelihood of various infectious disease event threats as well as assessments of risks and benefits for the global context. Measures that have co-benefits and lower likelihood event based activities may receive ODA funding to alleviate the opportunity costs of defunding other public health efforts (Abi Younes et al., 2020)(Burdet et al., 2018).

3.16 Training Healthcare Workers for Pandemic Responses

Training programs should incorporate simulated scenarios of pandemic situations. This allows the roles of healthcare workers to be defined and provides a setting for trialing different response measures. Different kinds of exercises may be used such as tabletop exercises, which can involve a large number of staff and require them to talk through their responses to a simulated scenario, to training specific groups of workers such as those who work for non-government organizations, using scenario simulation followed by debriefing and evaluation. Simulation exercises can help identify weaknesses in pandemic response plans and areas in which healthcare workers are unclear about their roles. An important part of training healthcare workers is having access to up-to-date information and educational resources regarding pandemics and how to respond to them. This can be done through providing relevant publications and resources, as well as easy access to training programs and skill development sessions (Akinyi Ondula & Krishnamachari, 2023)(Pine et al., 2023).

Training healthcare workers is an important part of preparing the public health system response. This is because healthcare workers need to understand their roles and the public health response to the pandemic. This would involve outlining specific pandemic response

measures and ensuring healthcare workers understand issues such as infection control and case management. Specific training programs for working in a climate of an infectious disease outbreak are needed to foster the development of an expert workforce in this field (Abedrabboh et al., 2020)(Lipsitch et al., 2023).

3.17 Enhancing Medical Supplies and Equipment

The international community benefits from addressing the issue of medical supplies through a collaborative effort. Coordinating the resources among affected countries can prevent extensive competition and stockpiling of medical supplies and equipment. This can be accomplished through regional or international networks that link developed countries with developing countries in a give-and-take fashion. Capacity building can occur for both sides as developed countries can provide technical assistance to procure the correct items required, while developing countries may be trained to make effective use of limited funding to increase the availability of supplies. A famous case would be the SARS pandemic in which the World Health Organization took an active role in coordinating resources and providing assistance with great success (K. den Nijs et al., 2022)(L. Sabogal De La Pava & L. Tucker, 2023). Global pandemics often cause quick and severe strains to a country's healthcare systems in various aspects. This boils down to a lack of sufficient infrastructure and resources for countries to be constantly prepared for a pandemic. Hence, a crucial preparation would be to enhance the infrastructure, supplies, and equipment as well as building the capacity of the healthcare system to respond to various needs during global pandemics. The closer the gap between the identified needs and the availability of medical supplies and equipment, the better a country will be able to protect the health of its population in a time of crisis (Neranjana Thilakarathne et al., 2020)(Tasnim Rodela et al., 2020).

3.18 Communication and Public Engagement

Several things should be kept in mind when designing the risk communication program for a pandemic. The situation is often characterized by a high degree of uncertainty; it is difficult to provide people with clear and specific information. However, even though information may be equivocal, people need guidance to plan their behavior. In such situations, there is a temptation to say either too much, leading to contradictory advice, or too little, leaving people without the information they need to protect themselves.

The central task of risk communication is to provide people with useful information that will enable them to take appropriate protective actions. This requires an understanding of people's information needs and questions, and the development of clear and consistent messages to address them (R Schneider et al., 2023)(Tasnim et al., 2020). Health officials and political leaders need to demonstrate competence in dealing with the crisis and show that they are in control. This helps to maintain societal calm and prevent a descent into crisis and chaos. At the same time, it is important to remain credible. Over-reassuring statements can backfire if they are seen as not credible, and refuted by events. This ultimately leads to a loss of trust. Finally, good risk communication is not a one-way activity in which experts inform the public. It is also essential to listen to people's concerns, address their questions, and engage with their fears and anxieties. This builds trust and allows officials to adapt their strategies in the light of public sentiment (Melis Kirgil, 2023)(Fadel Arandas, 2023).

3.19 Risk Communication Strategies

To address the complex and uncertain nature of pandemics, successful risk communication is essential. Risk communication has been defined as an interactive exchange of information and opinions among individuals, groups, and institutions. Effective risk communication can build trust in public health decision makers, which proved to be a critical factor in both the SARS and influenza experiences. During the SARS outbreak, lack of

information and misinformation fueled anxiety and undermined public trust in public health institutions (Leng et al., 2020)(Battiston et al., 2020). Conversely, open communication was an important factor in controlling the outbreak in Canada. Written daily situation reports and regular press briefings improved public understanding of the disease and the government's response. When the threat of pandemic influenza materialized in 2009, the US Centre for Disease Control held frequent press conferences to communicate with the public and provide timely updates about the severity of the disease and recommendations for prevention. An evaluation study found that public satisfaction and perceived credibility of the CDC was high, and the risk messages were generally understood by the public. High public satisfaction was also seen in Taiwan during the SARS crisis, where telephone hotlines were available for the public to seek information, and the health authorities were praised for their openness in daily media interviews (Morales et al., 2021)(Pettinicchio et al., 2021).

3.20 Public Awareness Campaigns

Awareness campaigns are a large part of communication strategies; however, while they specifically create knowledge to change behavior, they may not be specifically designed to reduce the risk of negative behavior. In today's society, people primarily gain their knowledge from television, newspapers, and internet information resources. Public awareness campaigns are sometimes needed to direct attention to the issues and educate how consequences of actions can impact health (Bada et al., 2019)(R. C. Nurse, 2021). One successful public health campaign was when the Queensland (Australia) government released an advertisement in 2007 showing what young overweight children would look like as obese adults. The campaign was designed to shock parents to encourage behavior changes in providing healthier food and activities for their children. This was a successful campaign in reaching its target audience as it created much media attention and the advertisement was one of the most viewed things on YouTube in that week, thus maximizing the coverage of the message (Deb et al., 2018)(Munir et al., 2022).

3.21 Addressing Misinformation and Rumors

Misinformation and rumors are commonly associated with outbreaks of infectious diseases and can have severe consequences for both the health of the population and the effectiveness of the disease control measures. The cause of rumors is often a mystery, but their spreading is facilitated by people's concern regarding the threat of the disease, the disease's unfamiliarity, or with no clear answers available. Rumors begin at a time when authoritative information is scarce or not immediately available. They provide an explanation or interpretation of an event or situation and often simply express people's fears (Tasnim et al., 2020)(Bae et al., 2020). They are a form of attempting to understand things which are not clear. Misconceptions occur at the end of an outbreak and are incorrect beliefs or understandings which are usually the result of poor communication. All have the potential of becoming deeply ingrained in the community's belief systems and may re-emerge at any time during or after the disease event. An incorrect assumption about rumors is that they will die out when the crisis is over. In fact, they can continue to pose problems long after the disease has gone. This is due to the fact that the slowing of the disease is what stops people discussing the topic and brings the rumor into informal activity discussions. Finally, rumors are difficult to combat. They tend to spread faster than the disease and are often more difficult to address than the disease itself. To effectively combat rumors, there must be a planned and systematic approach (Zhao & Settippalli, 2023)(Yang et al., 2021).

3.22 Research and Development

The development of new tools and technologies for the prevention, early detection, and control of infectious diseases is crucial to improving the resilience of populations to those

threats, in general, and to the threats of pandemic infectious diseases, in particular. "Research and Development" has often been overlooked as a core public health function both in industry and in government with emphasis in the former on product development and in the latter on basic science research. In recent years, the landscape has evolved, particularly in the area of vaccine development, with greater involvement of industry in product development activities and a growing global imperative for development of vaccines for diseases that predominantly affect the world's poor. This new landscape has significance for public health preparedness and for the globalization of research and development (Maity et al., 2023)(Chindelevitch et al., 2022).

3.23 Vaccine Development and Distribution

A present lack of capacity has also been highlighted by the fact that vaccine production for recent epidemic and pandemic diseases has lagged in the wake of actual threats. This has been exemplified by the H1N1 influenza pandemic where although the pandemic strain was identified rapidly by WHO, vaccines were not produced or available for 6-7 months post identification of the virus. This vaccine lag occurred largely in part to the fact that development of vaccines for seasonal influenza is predominantly conducted in the private sector vaccine industry, and there was insufficient infrastructure and incentives in place for the industry to rapidly switch production to a pandemic strain vaccine. The net result was that there was no significant pandemic vaccine production above the seasonal influenza vaccine, combined with a large and understandable reluctance of the developing world to purchase, or even accept donation of H1N1 vaccine, given that most H1N1 disease and mortality was occurring in lower income countries, which did not have H1N1 vaccine during the pandemic (Kirchhelle, 2020).

The recent epidemics of SARS and pandemic influenza have resulted in an understanding of these problems, and have spurred some initiatives to rectify the situation. This has involved convening major stakeholders to agree on a plan for R&D of specific vaccines against epidemic infectious diseases, and has led to accelerated pathways for regulatory approval. These are positive steps and what is needed now is continued and sustained investment in these initiatives, and a further developing of the understanding of best practice in vaccine R&D, such that these activities may be carried out by existing and new global public-private partnerships, the pharmaceutical industry, and the public sector at large (Haghani & C. J. Bliemer, 2020)(M. Batistela et al., 2021)(S. Wagner et al., 2022).

Vaccine development and production is a critical part of addressing pandemics. Unfortunately, the modern vaccine industry is based on a business model which does not prioritize pure public health needs, and there are major gaps in our knowledge of how to best produce new vaccines. Little progress has been made in developing vaccines against emerging infectious diseases, and there are also viral diseases globally which have no vaccines, and no research programs ongoing to develop them. But while adequate public sector investment in vaccine research and development is lacking, there is also a suboptimal coordination of existing expertise (Abi Younes et al., 2020).

3.24 Antiviral and Therapeutic Research

In the case that the pandemic strain is resistant to current antiviral drugs, or in the event of an antigenic shift of avian influenza resulting in a human pandemic, there exists an urgent need for new antiviral drugs that have a novel mode of action and/or are effective against all influenza virus subtypes. Such an event has the potential to attract pharmaceutical industry investment into influenza research, and there are a number of ways in which public-private partnerships could be used to facilitate rapid development and stockpiling of new drugs. A recent study in the US concluded that it is feasible, if funding is available, to make a substantial impact on global public health preparedness by developing antiviral drugs to treat pandemic influenza (Pannu, 2020). This would involve a targeted research program to greatly

increase the knowledge base on pharmacokinetics, efficacy, and adverse event profiles of existing drugs in different age groups and populations with different health status. The same trials used to test alternative uses of existing drugs could also be used to test off-patent drugs that are not currently licensed for use in some countries. This would help to build a cheap and readily available stockpile of drugs that are known to be effective. Finally, new drugs could be developed and stockpiled, but it is predicted that current knowledge provides ample opportunity to greatly increase the availability of drugs to treat pandemic influenza within a 10-year time frame (Bradley et al., 2020)(H. Fefferman et al., 2020).

Too much emphasis has been placed on vaccines as the most effective way to mitigate the risk of pandemic influenza. With the imminent potential for a sudden emergence of a new pandemic strain, the limitations of vaccines are that they take time to develop and produce, have a short shelf-life, and may not be matched well to the emergent strain. It may take several months from the beginning of a pandemic for a vaccine to become available. For the first several months, the only pharmaceutical interventions to mitigate illness and slow transmission will be antiviral drugs and antibiotics to treat secondary infections. As mentioned previously, a coordinated international stockpile of these drugs and knowledge of how best to use them will be essential (S. Golan et al., 2020)(Gehl Sampath & Pearman, 2021).

3.25 Advancements in Diagnostic Tools

A baseline of disease absence is required for effective monitoring and containment of an infectious disease, and it is essential that tools are available to confirm when disease is not present. This is extremely difficult to achieve for many diseases, and there is a constant threat of re-emergence, e.g., rinderpest and its recent unofficial re-emergence in wildlife in India. Disease surveillance is important at all times but particularly during international disease outbreaks, and there is an increasing shift towards integration of surveillance systems for human and animal diseases. This should enable more effective control measures through shared information and technology between human and veterinary medicine (Sansom & A. Valiente Kroon, 2022)(Nasir et al., 2021).

One significant breakthrough in recent years has been the development of molecular typing tools. In the context of an epidemic, it is important to be able to differentiate circulating strains of an infectious organism both from non-pathogenic strains and from other pathogens. This information is vital for accurate disease diagnosis and implementation of appropriate control measures (Clément et al., 2018)(Mustonen et al., 2018).

3.26 International Collaboration and Cooperation

The international spread of a global pandemic warrants the need for increased international collaboration and cooperation. As one affected country's experiences and best practices can serve as lessons learned for another country similarly at risk, mechanisms to effectively share this information are needed. One such example can be tracking the international spread of the pandemic among affected countries. This information can serve to predict the future impact of the pandemic on other countries and can help to direct the allocation of resources. This tracking could be achieved through the use of the internet and regular informal communication between countries, or could involve WHO facilitation of a formal information sharing agreement among member states. Another example, regarding best practices and lessons learned, could involve a developed country providing guidance and technical assistance to a developing country on how best to control the spread of the disease and reduce morbidity and mortality (C. Danko et al., 2023)(adams & Light, 2020).

A particularly important area of international collaboration involves the provision of support from developed countries to less developed countries. This support can take many forms, including the sharing of technical knowledge and expertise, the provision of essential resources and direct assistance in combating the disease. An excellent example of the sharing

of technical knowledge might be an epidemiologist from a developed country providing training to his counterparts in a developing country on the methods and techniques for disease surveillance and control (de Rijk et al., 2021)(Maity et al., 2023). The WHO or other aid agencies may facilitate the provision of essential resources, such as medical supplies or manpower, from developed to developing countries. This can help to ensure that the developing countries are not overwhelmed by the disease and can continue to function effectively. A good recent example of direct assistance involved the Australian-led international intervention force to assist control the spread of disease and provide increased public security in the Solomon Islands during civil unrest in 2003. Any such cooperative efforts must be carefully coordinated to ensure that they are targeted to areas of greatest need and are not to the detriment of the providing country's own public health and security (Alexandra Ramos et al., 2022)(Ayuso & project, 2023).

3.27 Sharing Best Practices and Lessons Learned

It is important to acknowledge, however, that the local context is extremely important in the applicability of lessons learned and best practices observed elsewhere. So global sharing of information will be most useful if followed by more focused efforts to understand what has worked under similar circumstances in different places, and to increase understanding of the contextual factors that led to variation in success of different practices. This might best be achieved through collaborative research/networks of researchers, and would contribute to a cycle of continuous learning and improvement of best practices for global public health emergency preparedness (Lipsitch et al., 2023)(Mahbub Hossain, 2022).

Those involved in efforts to control epidemics and other public health emergencies should make an explicit and extensive effort to create and maintain an easily accessible clearinghouse of information about best practices and lessons learned from the experiences of others. This will include support for academic efforts to create searchable databases of information from multiple sources, including surveillance and epidemiologic data, clinical findings and results, and public health prevention and control measures. It will also include encouraging the publication of information in readily accessible formats (e.g. more rapid publication of research findings, open-access formats) and resources, and creation of new resources (e.g. standard operating procedures, toolkits, training resources) focused on best practices. To the maximum extent possible, such resources should be collected in a single location with unified search capabilities for easy use. Finally, transparency in reporting should always be encouraged with the understanding that open sharing of even the most difficult experiences (F. Mello et al., 2020)(Cole, 2020).

3.28 Joint Efforts in Surveillance and Response

The spread of infectious diseases across borders has demonstrated the critical role of international collaboration in order to minimize human and economic losses. As seen in the SARS outbreak and the recent H1N1 epidemic, timely information sharing and a coordinated global response are essential. Successful collaboration starts with the development of trust and the establishment of a culture of sharing. In terms of surveillance and response, resource sharing and coordination among developed countries has been strong. However, the same cannot be said for data sharing and coordination among all nations. There are large disparities in technical, financial, and human resources for health among countries, yet global infectious disease threats affect all. A more equitable approach to resource sharing and global solidarity is needed. The recent pandemic of H1N1 influenza has brought this issue to light with concerns over vaccine availability for developing countries. Through surveillance and information sharing, it has been clearly shown that the global spread of H1N1 made no distinctions between countries in the level of impact. Yet without the availability of vaccines and other medical countermeasures, the most severely affected countries will continue to be at higher

risk, creating a vicious cycle of continued disease impact (Beigi, 2020)(Galaz & Meacham, 2024).

The revised International Health Regulations and the implementation of its requirement in many countries for a State Party to create a National Focal Point and designate points of entry for infectious disease are steps in the right direction for facilitating global surveillance and data sharing. The use of digital technology and open source information for identification of disease outbreaks has created new possibilities for global information sharing and coordination. An example is ProMed mail, an internet-based reporting system designed for global infectious diseases and foodborne outbreaks. Despite these advances, there is a clear need for further development and more resources for global surveillance and rapid data sharing. In facing the continually increasing complexity of global infectious disease threats, the global community must continue to innovate in its efforts and adapt new technologies for better global coordination and surveillance. This is essential for the creation of a safer and more secure world in the face of global health threats (Shahid Abbas, 2023)(Pannu, 2020).

3.29 Mutual Aid and Support Networks

The goal of achieving mutual aid and support networks is a lofty one, particularly in a highly competitive environment. However, the importance of these networks is clear to health experts and policymakers; their attainment is viewed as an essential component of a global strategy for disease prevention and control. Such networks can take various forms. Direct mutual aid among countries or organizations in the form of personnel, expertise, and resource sharing are the most familiar. Ideally, effective support networks will also provide assistance to stricken areas while they are still recovering from a disaster. This can be facilitated through the development of twinning programs between more and less developed countries or from regions of countries. In the WHO's World Health Report 2007, much discussion is given to the concept of a fund to provide assistance to countries suffering from health emergencies or crises (Yang et al., 2019)(Manríquez & Guerrero-Nancuante, 2021).

This could potentially serve as an important vehicle for support, although the complexities of its operations and its governance would need to be worked out meticulously to avoid pitfalls that similar programs have encountered. An often overlooked aspect in the creation of networks is the generation of an infrastructure and culture that facilitates the establishment and maintenance of relationships that continue to yield benefits over the long term. This will be a challenge as it is human nature to respond to an immediate threat but then move on to other priorities once the threat has dissipated (Schulzrinne, 2018)(van Elteren et al., 2024). The recent Global Health Security Agenda (GHSA) is an important new initiative, leveraging much previous work on the International Health Regulations and other initiatives to create a 5-year multilateral effort with the goal of making the world safer from global health threats. This initiative aims to advance a variety of global health security capacities with measurable outcomes. Successful implementation of the GHSA would be a major step towards the achievement of the global strategy (Pannu, 2020)(Ferreira, 2023).

3.30 Evaluation and Continuous Improvement

The ability to test rival strategies against the same model of the threat environment, and to run the model numerous times for each strategy in order to ensure that failures are not the result of bad luck, is a major advantage of decision analytic approaches over projections based on historical data. This kind of analysis is particularly relevant to public health planners. For example, a decision tree can be used to model the response to an emerging communicable disease and compare the costs and health outcomes of various containment and mitigation strategies. The software can provide continuous feedback on the progress of the epidemic and the performance of each strategy in real time, enabling quick adaptation of strategies as lessons are learned from their relative successes and failures (M. Baker et al., 2020)(Strong et

al., 2021). An argument for the allocation of additional resources for preparedness is that the marginal benefit of additional resources for public health interventions may increase, rather than decrease, as preventive capacity increases. This is because improved capacity to detect and manage threats may prevent escalation to higher cost interventions, and the ability to effectively manage a threat may prevent similar threats from emerging in the future. Dynamic analytic approaches are the only way to test this hypothesis (Ogilvie et al., 2019)(Maity et al., 2023).

The most important difference between paper and software approaches to evaluation is that software analysis can provide continuous feedback on the performance of strategies and can support dynamic adaptation of the strategy being implemented. In contrast, traditional IP models provide a comparison of a single run of a specific alternative strategy to the base case (i.e. what happened in reality). This provides an estimate of the net benefit of the alternative strategy by comparing predicted outcomes to reality, but does not say whether the strategy was the best possible, given the information available at the time it was implemented. In reality, the strategy that was implemented evolved over time in response to the success or failure of each of its components or the appearance of new information (Schroeder de Witt et al., 2020)(Lipsitch et al., 2023).

3.31 Monitoring and Evaluating Preparedness Efforts

A thorough evaluation of the progress in pandemic preparedness is essential in ensuring continuous improvement. Several types of exercises will have been conducted in the life-cycle of the pandemic preparedness program. Initial table-top exercises may be used to determine the understanding of roles and levels of preparedness among individuals and organizations with a defined level of response. Full-scale exercises aim to practice and evaluate the overall function of public health and emergency response systems, often with scenarios that simulate the stress of a real event. These exercises provide an objective test of plans and skills and help identify systems in need of improvement. Evaluative methods for these exercises should include the use of after-action reports or hot wash sessions, which are debriefings that occur immediately after the exercise to discuss what happened and how things can be improved. Measures of improvement and lessons learned should be compared against original objectives and performance indicators. Simulation models should monitor changed inputs that reflect strong evidence-based data or identification of areas of weak evidence (Hays & Jules White, 2024)(Ning et al., 2022). Outputs can be compared against simulation predictions to evaluate effectiveness efforts at various stages of a pandemic. Economic analysis and cost-effectiveness comparisons should also be used to guide policy decisions towards strategies that provide best value for money. Regular monitoring of resources devoted to pandemic preparedness effort and comparisons against objectives and resources required will help decision makers to optimize funding allocation. Finally, surveys and interviews can be used to gauge stakeholder opinion and involvement and identification of attitudes and beliefs which may affect preparedness efforts. These will provide valuable insights into the political and social context of preparedness and how it might best be approached. All data collected should be stored in an accessible form for periodic review against future objectives and to aid future research (Alamo et al., 2020)(Alamo et al., 2021).

3.32 Incorporating Lessons Learned into Future Planning

After action reports are critical tools to evaluate the effectiveness of planning and exercising efforts and to improve preparedness for the next event. They should include qualitative and quantitative data on the response effort, along with strengths, areas needing improvement, and recommendations to enhance the response. Qualitative data should include a chronology of the event, actions taken, and outside influences on those actions. The quality of the event response should be assessed in terms of relevance, timeliness, effectiveness, and

efficiency of actions taken. Key findings from reports should be used to modify plans and develop new initiatives to enhance response (Hays & Jules White, 2024)(Bianchi et al., 2023).

Lessons learned processes should be integrated with both public health and emergency management systems in a country, and with relevant partner organizations, for example hospital and laboratory networks, to ensure that action is taken to improve the effectiveness of the response. Key findings should also be disseminated to government policy makers and political leaders, so that they understand the importance of maintaining and enhancing public health emergency preparedness and response, and have an understanding of the resource needs to accomplish this (Pastor-Escuredo, 2021)(H. Fefferman et al., 2020).

3.33 Adapting Strategies based on Changing Threats

The resources required to address specific or differing threats will come from the establishment of effective global and domestic public-private partnerships. It is likely that some threats require the development of specific new resources. An example of this is the effort to increase the surge capacity of the US acute health care system which was a result of recognizing that bioterrorist attacks or severe naturally occurring disease outbreaks could quickly overwhelm the system. In other scenarios it may be more effective to allocate existing resources in a different way. An example of this is the use of a variety of new information technologies in the early detection and prompt effective global communication on potential public health threats. These information system resources can be applied to virtually any type of threat, and thus are conducive to the all hazards approach (Perazzini, 2020)(Xiong et al., 2020).

Monitoring and evaluation will result in the identification of successful strategies, as well as areas for improvement. As the global public health infrastructure and capacity improves, the threats faced and the resources available to address them will also change. It is important for planning efforts to be flexible and to be able to shift resources to address new highest priority threats. The results of the GAP Analysis will provide the necessary information to determine where shifts in resources are needed. The key to adapting strategies is the development of an all-hazards approach. With a focus on the tasks and resources that are common to addressing a wide range of threats, the public health system will be better prepared to address anything from a bioterrorist attack to the next naturally occurring emerging infectious disease (Kirchhelle, 2020)(Kirchhelle, 2020)(Ayuso & project, 2023).

4. Conclusion

Key activities involved in public health preparedness for a global pandemic include:

1. Surveillance and Monitoring: Establish a robust surveillance system to detect and track potential outbreaks early, enabling timely response and containment efforts.
2. Risk Assessment: Conduct a comprehensive risk assessment to identify potential threats, vulnerabilities, and areas for improvement in preparedness plans.
3. Resource Allocation: Ensure adequate allocation of resources, such as medical supplies, personnel, and funding, to support response efforts during the pandemic.
4. Emergency Response Planning: Developing a comprehensive response plan that integrates public health actions with broader community strategies to address the social, economic, and political impacts of the pandemic
5. Global Coordination: Collaborate with international partners and organizations to develop a unified global response strategy, prevent duplication of efforts, and optimize resource utilization.
6. Training and Capacity Building: Provide training programs for health workers, emergency responders, and communities to improve preparedness and response capabilities.

7. Communication and Information Sharing: Establish effective communication channels to disseminate accurate information, overcome disinformation, and interact with the public during the pandemic.
8. Evaluation and Improvement: Continuously evaluate preparedness efforts, identify successful strategies, and implement improvements based on lessons learned from past events.

By engaging in these activities and adopting a proactive approach to public health preparedness, countries can improve their preparedness to respond effectively to global pandemics and protect the health and well-being of populations around the world.

Strategies to ensure that health systems remain flexible and able to meet the needs of affected populations during the global pandemic include:

1. Health Care Infrastructure and Capacity Building: Investing in health infrastructure to increase capacity to provide effective care and respond to surges in demand during the pandemic. This could involve building new facilities, adapting existing structures, and prioritizing resources for the pandemic response.
2. Health Systems Strengthening: Conduct an assessment of the health system's capacity to cope with anticipated surges during the pandemic and establish a review process involving key ministries to ensure preparedness and coordination.
3. Multi-Sector Approach: Adopt a multi-sector approach to pandemic planning by involving non-health partners from the earliest stages of plan development to minimize community disruption and increase response effectiveness.
4. All-Threat Approach: Implement an all-threat approach in preparedness planning that can be applied to a variety of threats, including pandemics, natural disasters, and other health emergencies. This approach maximizes resource utilization and avoids duplication in planning efforts.
5. Flexibility in Infrastructure Design: Design health facilities that are versatile, scalable, and adaptable to changing circumstances and infectious disease control requirements. Incorporate the latest knowledge in infection control measures to prevent the spread of epidemics within healthcare settings.
6. Resource Allocation and Mobilization: Develop a resource allocation and mobilization plan that allows for moving resources to address new priority threats based on monitoring and evaluation results. This ensures that health systems can adapt to evolving challenges and respond to emerging infectious diseases.

By implementing these strategies, health systems can increase resilience, responsiveness, and ability to meet the diverse needs of affected populations during a global pandemic.

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