Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

_____   April 17, 2022
Bernard Owusu Agyare   Date

Transforming Global Health Security to Prevent, Detect and Respond: A Systematic Review of Workforce Development

By

Bernard Owusu Agyare
Master of Public Health

Hubert Department of Global Health

_____
Scott McNabb, Ph.D.
Committee Chair

Transforming Global Health Security to Prevent, Detect and Respond: A Systematic Review of Workforce Development

By

Bernard Owusu Agyare
Foege Fellow – Rollins School of Public Health, Atlanta, Georgia
BSc. MPH, Kwame Nkrumah University of Science and Technology – 2010, 2013

Thesis Committee Chair: Scott McNabb, Ph.D.

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Hubert Department of Global Health
2022

Abstract
Transforming Global Health Security to Prevent, Detect and Respond: A Systematic
Review of Workforce Development

By Bernard Owusu Agyare

Introduction: The COVID-19 pandemic has exposed deep cracks in the global health security architecture. Although the health workforce has a responsibility to prevent, detect and respond to health threats, workforce is usually insufficiently prepared and uncoordinated. This systematic review aims to examine the state of the global health security workforce, identify gaps in workforce development and offers recommendations to transform global health security to effectively prevent, detect and respond to health threats.

Methods: The study searched PubMed™; Web of Science™; and ERIC™ databases for English-language literature on global health workforce development published between January 2000 and December 2021. Electronic searches for selected articles were supplemented by manual reference screening. The review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.

Results: Out of 1,437 citations retrieved from the electronic searches, 37 articles were included in the review. There is increased interest in health workforce development activities immediately after a global health event. National governments, the World Health Organization (WHO) and the United States Centers for Disease Control and Prevention (CDC) were identified as the major stakeholders in workforce development whereas Physicians, nurses, and epidemiologists were identified as key professionals responsible for maintaining global health security. There was no specific tool or framework for the enumeration of workforce to identify demand and supply projections. Blended learning (combining online and in-person instruction) was identified as the preferred training modality for workforce development.

Conclusion: Findings suggested that there was no clear definition for global health security and which professions should constitute the global health workforce among stakeholders. There was also little recognition from stakeholders in animal and environmental health which undermined the principles of One Health. The study also identified that most workforce development frameworks were vague on indicators and competencies expected of the different cadre of health workforce. There was the need for sustained investment in global health workforce and enhanced collaboration between the human, animal and environmental health.

Transforming Global Health Security to Prevent, Detect and Respond: A Systematic Review of Workforce Development

By

Bernard Owusu Agyare
Foege Fellow – Rollins School of Public Health, Atlanta, Georgia
BSc. MPH, Kwame Nkrumah University of Science and Technology – 2010, 2013

Thesis Committee Chair: Scott McNabb, Ph.D.

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Hubert Department of Global Health
2022

Acknowledgement

I am most grateful to God for the boundless opportunities and for seeing me through this level of university education. His grace, love, direction and protection has been enormous.

My deepest appreciation goes to my supervisor, Dr. Scott McNabb, an internationally acclaimed expert in global health security. Dr. McNabb has been a great mentor throughout this thesis project. Despite his numerous schedules, he found time to promptly address my concerns. More importantly, he always believed in my potential, and provided constructive feedback that helped me to stay focused from the beginning.

I am also grateful to Dr. Bill Foege and Dr. Deborah McFarland, manager of the Foege Scholarship Award for considering me for this scholarship that enabled me to enroll in this prestigious school and program. I also acknowledge and appreciate Shenita Peterson (Senior Librarian, Emory University) for her contribution towards this work.

Finally, I dedicate this work to my wife (Ohemaa), my two children, my mother (Cecilia) and my siblings (Prince, Monica, Martha and Mary).

Table of Contents

ABBREVIATIONS

BWC	Biological Weapons Convention
DURC	Dual Use Research of Concern
EHF	Ebola Hemorrhagic Fever
EOC	Emergency Operation Centers
EWARS	Early Warning Alert and Response System
FAO	Food and Agriculture Organization
FETP	Field Epidemiology Training Program
GHSA	Global Health Security Agenda
GIBACHT	Global Partnership Initiated Biosecurity Academia for Controlling Health Threats
HSS	Health Systems Strengthening
IHR	International Health Regulations
IPC	Infection Prevention and Control
JEE	Joint External Evaluation
MERS	Middle East Respiratory Syndrome
OIE	World Organization for Animal Health
PAHO	Pan-America Health Organization
PHEIC	Public Health Emergency of International Concern
PoE	Point of Entry
SARS	Severe Acute Respiratory Syndrome
US CDC	The United States Centers for Disease Control and Prevention
WHO(A)	World Health Organization (Assembly)

CHAPTER ONE

1.0   Introduction

Global interconnectedness makes the spread of dangerous pathogens across geographic areas easier. (Re)emerging pathogens, as well as climate-related health events, pose significant threats to humanity.[1,2] They are associated with high morbidity and mortality, plus psychological and emotional tolls on individuals and families.[3] They lead to declining national economies, unemployment, and disruption of existing health programs.[4] To protect humanity from these devastating consequences, adequate public health preparedness and response are required.[5] According to the Organization for Economic Co-operation and Development (OECD), pandemic preparedness and response are "*quintessential global public goods*" that must be actively pursued.[6]

The ongoing COVID-19 pandemic exposed deep cracks in the global health security architecture.[7,8] The failure to mount prompt and coordinated worldwide (and national) responses – especially during the initial stages – showcased lapses in pandemic preparedness and response. This stems, in part, from an insufficiently prepared and uncoordinated frontline public health (PH) workforce. The lack of PH-prepared workers was not peculiar to low- and middle-income countries (LMICs) (e.g., as during Ebola) but also among highly income countries (HICs). Additionally, the COVID-19 pandemic highlights just how working in professional silos severely undermined responses to a crisis of such magnitude.[9] This raises questions about the current paradigm for PH workforce development.

Various frameworks of global health security workforce development have been designed, mostly in reaction to prior global health events. For instance, after the world recovered from the trauma of the severe acute respiratory syndrome (SARS) pandemic

in 2003, the International Health Regulations (IHRs) was revised and adopted by the World Health Organization.[10,11] This revision of the IHRs was to ensure global health security by coordinating and supporting global health efforts to prevent, detect, and respond to the international spread of diseases.[11] However, the core capacity that addressed PH workforce was vague. The effect has been a slow and lackluster response to subsequent pandemics, especially the current one causing significant worldwide morbidity and mortality, economic hardship, fear, and anxiety.

Tragically, experts continue to warn of future pandemics with greater consequences. To ensure humanity is well prepared, the urgency to modernize global health security – particularly in workforce development – is far more apparent.[12] The lack of an exact definition for the global health security workforce; what cadre of professionals should constitute this workforce; what pre-service and in-service training needs might be; and what a universal framework outlining competencies might look like are gaps.

Despite the importance of workforce development, research is limited. Although some published literature on the topic have offered diverse solutions, they do not address how these solutions can be applied universally. Existing literature fails to consider the impact of contemporary global health issues (e.g., climate change, synthetic biology, and neocolonialism) on workforce development. This study examined the gaps in global health security workforce development and offered recommendations applicable to contemporary issues.

1.1 Background

We have experienced five pandemics in the 21st century: severe acute respiratory syndrome (SARS-CoV-1) in 2002; H1N1 in 2009; Middle East Respiratory Syndrome

(MERS) in 2012; Ebola in 2013; and COVID-19 (SARS-CoV-2) from 2019 until now. Drivers (e.g., rapid population growth, urbanization, and land conversion) led to the unprecedented intermingling of wild animal and insect species, humans, and domesticated animals.[13,14] This cross-species pathogen exposure results in the increased emergence of novel human pathogens.[15] In this interconnected world, diseases and other health threats transcend geopolitical boundaries through international travel and trade.[16] This implies that a single health event in any country can rapidly spread and seriously undermine the health, economy, and social livelihood of the entire global community.

Sadly, the global community has responded only reactively to these pandemics. Various frameworks and resolutions have been formulated and implemented in the aftermath of these devastating pandemics; the International Health Regulation (IHR) was revised in 2005 (and became legally binding on member states in 2007). Not long after, three major pandemics – H1N1 in 2009; Middle East Respiratory Syndrome (MERS) in 2012; Ebola in 2013; – shook the very foundation of the newly revised IHR 2005.

As in the past, global health leaders reacted by formulating the Joint External Evaluation (JEE) in 2015; a competency-based assessment of health security preparedness. Various JEE reports were released to highlight how countries (especially industrialized nations) were prepared to deal with future pandemics.[17] However, the COVID-19 pandemic has exposed inherent gaps and flaws in these assessments. Evidently, the world was unprepared; response was spontaneous, uncoordinated, and chaotic at global and national levels.[18,19]

Pandemics are associated with significant human, economic, and social costs. These costs are even much dire if adequate mitigation strategies are not in place or enforced.

According to the U.S. Center for Disease Control and Prevention (CDC), between 151,700 and 575,400 people died worldwide from H1N1 in 2009.[20] WHO reported a case fatality rate of 35% from MERS in 2012.[21] and 11,462 died from Ebola in 2013.[22] COVID-19 has claimed > 5,000,000 lives; and this count is sadly still rising.[23] The economic and social impact of these pandemics are incalculable. Researchers and global figures continue to warn of future pandemics with even greater magnitude. These warnings must be taken seriously to save humanity from impending disasters. The need to invest in training and preparedness of the global health workforce is more than apparent.

Workforce development cannot be overemphasized. Health systems can only function with the availability, accessibility, acceptability, and quality of healthcare workers.[24] Healthcare workforce is one of the six components of WHO's health system strengthening framework. In fact, a country's ability to meet its health needs will depend on the knowledge, skills, motivation, and deployment of the health workforce.[25] Therefore, health system capacity is intricately connected to a country's *health workforce capacity and sustainability.*[26] In a broader context, addressing global health workforce development would support national health system strengthening.

Additionally, a clearly defined workforce development strategy will address some impediments to the implementation of One Health. One Health is an inter-disciplinary approach with an overarching goal to foster coordination, communication, and collaboration among relevant national and international institutions, ministries, and stakeholders for human, animal, and environmental health. This coordination, communication, and collaboration serves as the strategic platform to share and utilize information and communication technology (ICT) supporting human and animal public

health surveillance (PHS); make evidence-based information available to relevant authorities; and implement actions that prevent, detect, and respond to health threats.[27]

During the early phase of the COVID-19 outbreak, ICT and data sharing among relevant human and animal health institutions was clearly lacking; this resulted in delayed declaration of a PHEIC by the WHO, and other public health actions such as testing and contact tracing.[28] The loss of immediate containment is a direct consequence of multi-disciplinary health actors operating in silos with little or no coordination, communication, and collaboration.

1.2   Problem statement

Pandemic events such as COVID-19 pose significant challenges to humanity. The human, economic, and social costs are incalculable. An estimated 259,258,632 have been infected with COVID-19 with global mortality over 5,172,314 as of Nov 24, 2021.[23] The 2014 – 2016 Ebola pandemic in West Africa was estimated to affect > 28,000 persons with 11,000 deaths.[22] Measures imposed by governments and health authorities to control pandemics also have a negative impact on mental health, especially children and young adults. The rate of depression and anxiety resulting from the COVID-19 lockdown was high.[29,30]

The economic and fiscal impact of COVID-19 has been disastrous. The global economy is estimated to have lost USD $53 billion due to Ebola[31] and USD $16 trillion from COVID-19 between 2020 and 2021.[32] Total and partial lockdowns plus closure of air, land, and sea borders led to an unprecedented interruption in global commerce and trade.[33] These measures affected the operation of many companies and forced some to downsize or

close, leading to unemployment and further exacerbating personal and household poverty.

The effect on smaller economies is more pronounced. With limited purchasing power, individuals and families were driven down the economic hill, deepening the inequalities that existed between the poor and the rich.[34] The global poverty rate which had seen a steady decline since the 1990s, could now see a sharp rise[32] derailing the sustainable development goal to end poverty by 2030.

Pandemics impose unbearable social costs on humanity and upset the norms of societal interactions and activities. Restrictions resulting from the closure of national borders and other forms of intra-nation measures (e.g., isolation and quarantine) effectively caused the separation of families in certain situations. There were reported high incidences of domestic violence, particularly Intimate Partner Violence (IPV) because of social distancing, self-isolation, and lockdown measures which are known to precipitate these abuses.[35,36]

Staying at home due to the closure of schools and the lack of playtime with peers increased mental health problems of children and young adults.[37] At the peak of the COVID-19 pandemic in 2020, 90% of school children were unable to attend school[38], a situation that negatively impacted academic performance of many children.[39] Evidence suggests that lockdowns increased violence and vulnerability of children. Reported cases of child abuse spiked during the lockdown periods.[40]

Existing health programs such as maternal and child health, immunization coverage, and chronic diseases are negatively impacted by pandemics; resources for these priority health programs are diverted to combat the epidemic, further exacerbating existing health

problems.[41] Lockdown and other restrictive policies can lead to reduction in the patronage of healthcare services, particularly among vulnerable populations. Events of such nature can disrupt health service delivery through loss of health staff, damage to health facilities, interruption of health programs, and overburdening of clinical services.[24]

The hemorrhage seen in these sectors could have been mitigated with prompt prevention, detection, and response measures. As a result of inefficient workforce development policies and procedures, the global health security workforce was unprepared and uncoordinated in its response to the COVID-19 pandemic. Many countries lacked robust preparedness plans, core public health capacities, and collaboration at the multi-sectoral levels which was further worsened by the lack of political commitment.[42]

The devastating consequences of pandemics and how to develop the workforce to prevent, detect, and respond is the motivation for this work. The gaps in the existing workforce development framework that contributed to lapses in response to real-time emergency required that literature on global health security workforce development be systematically collected, reviewed, analyzed, and recommendations made to modernize existing workforce development approaches. The modernized global health security architecture must be firmly grounded in a highly trained, efficient, coordinated, and decentralized workforce.

1.3   Purpose statement

This systematic literature review examined and evaluated past and current efforts made by international bodies, national governments, multi-lateral organizations, and educational institutes to address global health security workforce development. Additionally, this review identified limitations and gaps in existing workforce development

frameworks and made recommendations to modernize workforce development to prevent, detect, and respond to emerging and re-emerging health threats.

1.4 Research questions

i. What are the existing frameworks for global health security workforce development?

ii. What is the composition of global health security workforce?

iii. How can the workforce be monitored to anticipate demand?

iv. What are the existing gaps in global health security workforce development and the recommendations that can be made to modernize it?

1.5 Significance

Pandemics such as COVID-19 and other climate-related health threats continue to wreak havoc on humanity. Globalization has made it easier for the spread of infectious diseases from any remote corner of the world to all countries within hours and days. Such events have tremendous human, economic, and social costs expensive to bear at the international, national, household, and individual levels.

Over the past 20 years, the world has experienced several pandemics with devastating consequences. Regrettably, research continues to show that pandemics and other health events of a larger scale still await humanity.[43] Therefore, the need to identify and address gaps in pandemic preparedness and response is crucial. At the forefront of protecting humanity from the devastating impact of pandemics is the health workforce.

It is imperative to review the state of the global health security workforce and the lack capacity to prevent, detect, and respond appropriately to past and present pandemics and health threats. It is also important to explore ways to build a stronger global health

security workforce with the capacity to prevent, detect, and respond to small- and large-scale epidemics that endanger humanity.

Findings from this review will be used by WHO and national governments to re-commit to the objectives of the International Health Regulations (IHR) by investing in health workforce capacities. Adequate investment in personnel, training, and logistics will ensure that the global health security workforce is well-prepared, equipped, confident, and motivated to prevent, detect, and respond to health threats.

This review will draw attention to global health decision-makers and stakeholders on the need to have a clearly defined *global health security workforce*. There is the need to expand the global health security workforce from the traditional hospital-centered approach to a more diverse scope. A clearly defined global health security workforce cadre will lead to a change in thinking in the scope of education and training, as well as the allocation of resources to the prevention, detection, and response to health threats.

This review will be used to advocate for a stronger commitment to the One Health Approach by the World Health Organization (WHO), World Organization for Animal Health (OIE), and Food and Agriculture Organization (FAO). It will highlight the advantages of strong investment in One Health at international, national, and sub-national levels.

CHAPTER TWO

2.0   Literature review

The literature was gathered on the global health security workforce as a tool to effectively prevent, detect, and respond to health threats. The various components of the health security architecture were explored. Existing frameworks on workforce development were also reviewed to highlight contemporary issues that should influence workforce development strategies.

The health workforce remains one of the key pillars of a strong and viable health system. The global health workforce has a responsibility to build the resilience of communities to prevent, detect, and respond to health threats.[24] To effectively mitigate the impact of global health events that threaten the health and wellbeing of humanity, the workforce must be trained, equipped, and strategically deployed.[5,44]

The COVID-19 pandemic raised fundamental questions about the capacity of the global health workforce to effectively perform its core responsibilities. To understand lapses in workforce functionality and offer recommendations that can help the workforce to respond effectively to future threats, it is important to understand the three core functions of the global health security workforce.

2.1   Pandemic and health threats prevention

Health threat prevention is the first pillar in the global health security architecture. Leavell & Clarck (1976) define prevention as a *calls for action in advance, based on knowledge of natural history in order to make it improbable that the disease will progress subsequently.*[45] To prevent is therefore to take pre-emptive measures based on scientific knowledge to avert the emergence of specific diseases or health threats.[46] Because more

than 60% of global health threats are zoonotic in nature, [47–49] preventive measures should be embedded in collaborative activities across multiple sectors – human, animal, and environment. Effective prevention requires capacity for infection prevention and control (IPC)[50] and emergency risk communication.[51,52] Kandel *et* al. (2020) posits that prevention of health threats requires reaching out to all persons and communities with concise prevention messages.[44]

2.2   Pandemic and health threats detection

Early and accurate detection of infectious agents whether emerging or re-emerging represents one of the most important pillars of global health security. According to the U.S. Institute for Medicine, detection requires *active vigilance for signs of an outbreak, rapid recognition of its presence, and diagnosis of its microbial cause.* [53] Gostin & Katz (2016) acknowledge that the longer it takes to detect an event, the slower the response which leads to higher morbidity and mortality.[49] This implies that surveillance is critical for the early identification of health threats. National early warning and alert systems (EWARS) which include Indicator-based and Event-based surveillance systems can be effective in the timely detection of health threats.

These surveillance systems utilize formal and informal channels to monitor and report health threats to appropriate authorities. Laboratory-based surveillance is another form of infectious diseases detection system that can harness technological advances in molecular methods to sequence and characterize infectious agents in a matter of days or even hours in some settings.[54]

The effective operation of these surveillance and detection systems depends heavily on a highly motivated, diverse, and intrepid workforce cadre; - clinicians, epidemiologists,

bioinformaticians, laboratorians, veterinarians, agricultural extension agents, point of entry officers, among others. These personnel are trained to notice unusual or suspicious symptoms and bring them to the attention of appropriate health authorities. In this regard, it is important that the health workforce is trained on quality standards and guidelines in the detection of health threats.

2.3   Pandemic and health threats response

The ultimate goal in maintaining global health security is the ability to mount an effective response to any health threat that has evaded prevention. Detection is not enough. It is important to respond appropriately. The aim of response is to stop, slow or otherwise limit the spread of the infectious agent. Approaches to response are wide and varied. Governments may decide to close air, sea, and land borders to control the international spread of diseases.[55] Total or limited lockdowns can also be imposed in certain jurisdictions.[56] Public health measures initiated in response to infectious diseases may include contact tracing and testing of suspected individuals, quarantine of exposed persons, and isolation of infected individuals.[57,58]

According to Patel (2019), an efficient public health emergency response requires a unified Command-and Control system and functional emergency operations centers (EOCs).[59] Olu *et* al., (2016) add that this incident command and EOCs setup will be responsible for creating rapid response teams and case management guidelines.[60] Davis *et* al.,(2021) and Parry *et* al., (2021) emphasize that workforce is critical for emergency response activities – human resources, funds, and logistics mobilization and prompt deployment.[61,62] Trained and motivated personnel are equally integral to responding to health threats at points of entry (PoEs). An appropriate response can be activated when

suspected cases are detected at points of entry to prevent the risk of transmission across national and international borders.

2.4   Existing global health security workforce development frameworks

The ability to prevent, detect, and respond to pandemics is reliant on workforce capacity. In the last two decades, various frameworks and policies have been designed to capture the inherent importance of global health security. These frameworks were developed in response to major global health events. Global health security workforce development has always been a key component in all of them. The International Health Regulation (IHR) core competencies, the WHO Health systems strengthening framework, the WHO Workforce development action plan, the Global Health Security Agenda action packages, and several international organizations have made provisions for workforce development in their frameworks.

These notwithstanding, the global health workforce appears helpless in the face of health threats. This helplessness was evident in the early phase of the COVID-19 pandemic and previous pandemics that have affected the world at the turn of the 21st century.

Figure 1: Global Emerging, Re-emerging, and Deliberately Emerging Diseases, 1981 – 2020
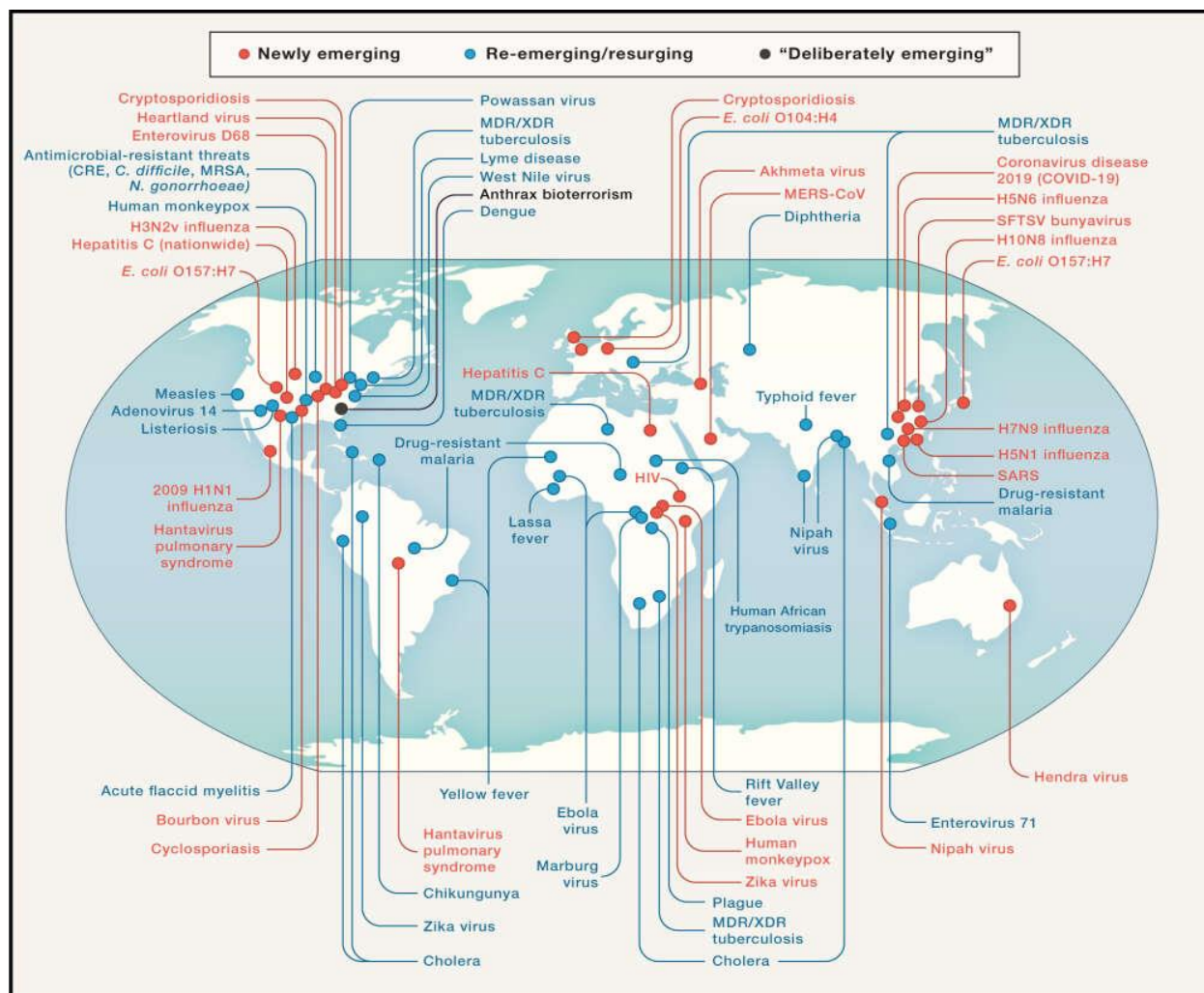
Credit: Fauci A & Morens D/Cell/2020 [63]

2.4.1   IHR framework

After the 2003 severe acute respiratory syndrome (SARS) pandemic, the World Health Assembly (WHA) passed resolution WHA56.29 to respond to global public health threats.[64] As a follow-up, resolution 58/3 of the United Nations General Assembly was adopted which underscored the importance of enhancing capacity building in global public

health and urged that priority should be given to this resolution. This led to the revision of the IHR in 2005 that became legally binding to all member states (MS) in 2007.[10]

The IHR (2005) is primarily designed to ensure that countries have the capacity to detect health events and give notification to appropriate reporting authorities. The IHR operates on a graduated reporting format for health events. For example, when a disease or deaths exceeds expected levels in a geographical area, health officials report to subnational or national levels. When health events that are deemed to have "serious public health impact or unusual with high potential for spread" are detected, they must be reported immediately to the national level where the event(s) must be assessed within 48 hours. Events assessed to warrant international concern, known as Public Health Events of International Concern (PHEIC), must be reported to WHO within 24 hours through the IHR national focal point.[65]

Because health workforce is integral to the IHR reporting system, one of the core capacities of the IHR is human resource or workforce development. Indicator 7.1.1 of component 7 of the IHR states that *human resources must be available to implement IHR core capacity requirements.*[11] This implies that MS are to ensure availability of sufficiently trained workforce to implement this objective. However, the workforce development indicator is vague and lacks specificity. The exact definition of health security workforce and the required competencies to effectively operate the IHR is conspicuously missing. The IHR provides no roadmap or guideline to support MS on workforce development strategies that include workforce needs, training needs, and development of a career ladder to improve retention for the various cadres required to ensure health security. This

lack of directionality has left MS to interpret health workforce based on their national priorities.

2.4.2   WHO framework on Workforce Development

To strengthen global health, WHO formulated the health system strengthening framework as an instrument to catalyze the achievements of health targets in the Sustainable Development Goals (SDGs). One of the six building blocks of the HSS framework is human resource development. According to WHO, *the health workforce constitutes "all people engaged in actions whose primary intent is to enhance health.*[65]

The report continues to identify the workforce to include clinical staff, such as physicians, nurses, pharmacists, and dentists, as well as non-clinical staff, such as managers, ambulance drivers, and accountants. The HSS workforce framework is focused on primary healthcare. Professionals such as laboratory staff, epidemiologists, public health officers among others who are integral to global health security are not mentioned.

A narrowed workforce scope in the HSS framework undermines the ability to efficiently plan and deploy workforce development resources. An inclusive global health workforce development is particularly important at a time when there is limited global and national financial investment in the health workforce. Therefore, a unified and multi-sectoral workforce development strategy should be pursued towards the concurrent achievement of the universal health coverage (UHC) and global health security (GHS) objectives.

2.4.2   Global Health Security Agenda Framework

The GHSA is a multi-national initiative launched in 2014. The aim of GHSA is to link MS, international organizations, and civil society together to prioritize health security activities and help countries to achieve core capacities of the IHR.[66] Ultimately, the GHSA seeks to achieve coordinated action and undertake specific, measurable steps to prevent,

detect, and respond quickly to emerging infectious diseases. To facilitate this goal, the GHSA has 11 action packages that provide guidance in prevention, detection, and response to health emergencies. These packages include baseline assessments, planning activities, and monitoring and evaluation activities that break down the broad issues of global health security into more discrete and attainable goals.

Action package 11 (AP) specifically addresses workforce development. The mission of the workforce AP is to sustainably enhance prevention, detection, and response activities through a fully competent, coordinated, evaluated, and occupationally diverse multi-sectoral workforce (e.g., physicians, veterinarians, biostatisticians, laboratory scientists, farming/livestock professionals). Indicator D.4.2 requires that Field Epidemiology Training Program (FETP) or other applied epidemiology training program must in place. In this regard, The workforce development AP is targeted for one trained field epidemiologist per 200,000 population, and one trained veterinarian per 400,000 animal units (or per 500,000 population).[67]

The GHSA is an improvement to the IHR because the framework acknowledges the importance of a health security workforce that is occupationally diverse and coordinated. The GHSA also presents concrete and actionable targets such as the number of trained epidemiologists or veterinarians per population. Notwithstanding, the GHSA framework still lacked specificity in some of the workforce indicators. The exact definition of the global health security workforce and the required training, level of proficiency and competencies to effectively prevent, detect, and respond to health threats are not defined. Additionally, although there is some form of accountability through the Joint External Evaluation (JEE)

process, these evaluations are voluntary. The Health Security Index only seeks to score countries' state of pandemic preparedness without any actionable steps.

2.5 International organizations and national governments commitment to workforce development

Some governments and international organizations actively support the global health security workforce in many countries through diverse pre-service and in-service training programs. The U.S. government, through FETP, assists the development of global epidemiology and public health surveillance (PHS) workforce capacities.[68] Since 1980, U.S. CDC through FETP has supported the training of over 18,000 disease detectives in more than 80 countries.[69] Similarly, the German government, through the Global Partnership Initiated Biosecurity Academia for Controlling Health Threats (GIBACHT) supports low- and middle-income countries (LMIC) to prevent, detect, and respond to health threats. GIBACHT aims to strengthen national and local centers for infectious disease epidemiology and management, biosafety and biosecurity, and the management of biohazards.

Since 2015, over 80 people from 18 different countries have received training in biosecurity.[70] The Biological Weapons Convention (BWC), Africa CDC Institute for Workforce Development (IWD), the International Association of National Public Health Institutes (IANPHI), the International Federation of Biosafety Association (IFBA), John Hopkins Center for Global Health Security are all examples of organizations and training programs that aim at building the capacity of the Global health security workforce.

2.6   Contemporary issues and workforce development

2.6.1   Climate change

Climate change remains one of the most important health threats to humanity and influences human health and disease in numerous ways.[71,72] Cavicchioli *et* al., (2019) note that climate change severely impacts water availability, food security, air quality, pathogen and vector dynamics, vector distribution and human habitat.[73] According to WHO report on climate change and health, climate change enormously affects the social and environmental determinants of health - clean air, safe drinking water, sufficient food, and secure shelter, and is estimated to lead to approximately 250,000 additional deaths per year between 2030 and 2050.[74] This implies that climate change poses a significant threat to global health security. Workforce development strategies should be cognizant of the impact of climate change on health security.

2.6.2   Biotechnology-synthetic biology

Synthetic biology is an interdisciplinary field that emerged at the beginning of the 21st century and has demonstrated immense potential for scientific research and application.[75] This novel technology allows researchers to quickly reconstruct, or engineer/modify viruses based on available viral sequence.[76] It has the potential to help humanity address critical issues such as health, environmental issues, energy, materials, among others. Conversely, unintended consequences of synthetic biology that stem from dual use research of concern (DURC) are sources of potential threat to global health security.[77] With this technology, biological agents can be weaponized either by state or non-state actors with devastating consequences for humanity. Biosecurity and biosafety workforce capacity needs to be developed within national health systems to survey and respond to the potential threats of emerging biotechnologies.

2.6.3 One Health

Existing workforce development frameworks highlight the importance of the One Health approach to infectious diseases prevention and control. Cutler *et* al., (2010) and Rozenbaum (2020) observed that most of the new pathogens that threaten humanity are zoonotic in origin.[78,79] Driving the increasing emergence of zoonotic diseases are land use, food production practices, and population pressure. The increasing interaction between humans, animals, and the environment makes it imperative to have a workforce that is versatile and interoperable across these disciplines.

One Health, an interagency and multisectoral collaboration between human health, animal health, and environmental health,[80] must be an integral part of pandemic preparedness planning.[81] Although most existing frameworks acknowledge the importance of One Health, health workforce development programs are mostly conducted in professional silos which undermines the principles of One Health.

2.6.4 Negative influence of neocolonialism

Global health and its precursor international health have historically been influenced by the agenda of individuals and organizations in high-income countries (HICs).[82] This unequal power dynamic has mostly disadvantaged partner institutions in low- and middle-income countries (LMICs).[83] Health workforce development is not immune from neocolonialism. Pre-service and in-service training curricula are mostly designed in the HICs with little to no consultation and consideration of the socio-cultural context of the LMICs. This state of donor dependency perpetuates neocolonialism in global health workforce training programs. The COVID-19 pandemic must be a watershed in future workforce training programs. Every country, rich or poor is at risk of health threats

therefore training should be collaborative and must involve exchange of best practices in pandemic preparedness and response.

2.7   Re-examine the health security workforce cadre

Contemporary issues such as climate change, biotechnology, and the emergence of COVID-19 should motivate global health security stakeholders to pause, reflect, and redefine the global health security workforce. An accurate definition of the global health security workforce would support the modernization of workforce development and training approaches. Dussault and Franceschini (2006) notes that health workforce development programs focuses on primary healthcare (curative).[84] Although there have been attempts to train epidemiologists and laboratory staff through the FETP and FELTP, other workforce cadres such as veterinary officers, public health informaticians, health communicators, points-of-entry (PoE) officers among other professionals whose work are important to health security are often overlooked. Workforce development should be more integrated in scope encompassing all relevant cadres.

2.8   Strengthening global coordination and capabilities

While nations must reinforce their capacities to prevent, detect, and respond to health threats, it is equally important to strengthen international collaboration and capacity-building solidarity. The COVID-19 pandemic has illustrated that the world is as safe as the most unprepared country. Infectious agents know no borders, so international cooperation is essential. Global health security is a global public good that requires collective action.

2.9   Summary

Global health security workforce has a primarily role to prevent, detect, and respond to (re)emerging health threats. Despite these existing frameworks, policies, and training

programs to build workforce capacity to prevent, detect and respond to health threats, the COVID-19 pandemic has exposed some inefficiencies and deep gaps. To provide clarity on this issue, we sought to perform a systematic review of the literature to (1) identify current frameworks that underpin workforce development and identify key stakeholders; (2) access current workforce development approaches that are effective and considered best practices; and (3) examine gaps in existing approaches and provide recommendations for modernizing the global health security workforce.

CHAPTER THREE

3.0   Methods

The study aimed to provide a systematic review of the literature regarding the global health security workforce and how it could be modernized to be effective to detect, prevent, and respond to (re)-emerging health threats. This systematic review was based on guidelines from five steps in conducting a systematic literature review.[85] Guidelines from Tricco *et* al., (2018) was used in to create the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow chart.[86] (Fig 2) Defined research questions were developed and, specific inclusion and exclusion criteria were identified to determine which studies to include in the review.

3.1   Literature search strategy

Literature search was conducted using three electronic databases: – PubMed™; Web of Science™; and ERIC™. PubMed™ and Web of Science™ were selected because these are commonly accessed databases by global public health experts and contain peer-reviewed articles published in journals with high Institute for Scientific Information (ISI) impact citation indices and with wide linkages to other high- profile databases. ERIC™ database was included in this search process because of the likelihood of identify literature that pertaining to education and capacity building for the health workforce. Additionally, ERIC™ database is frequently used researchers conducting studies on other aspects of public health workforce.[87] Google search engine was used to identify grey literature.

A widespread search strategy identified the maximum number of appropriate studies in each database. All possible formulations of the terms (combined with Boolean operators) were used in the search performed between Jan 28 – 31, 2022. Three electronic

databases were searched for articles published between Jan 1, 2000 and Dec 31, 2021.

Search terms included "public health workforce" OR "global health workforce" OR "health personnel" OR "human resources for health" OR "health workforce" OR "health manpower" AND "workforce development" OR "human resource development" OR "capacity building" OR "skill development".

Additionally, a combination of related search terms: "global health security workforce development framework" was applied to expand the search strategy. Grey articles were manually searched, identified, and included provided they met the eligibility criteria.

We supplemented the academic literature search with a search of grey literature using similar search terms. The search included WHO reports and national strategic response plans; this gave authentic reflections of the rapidly evolving landscape to guide key stakeholders.

Citations were exported to a citation management system, and sources were screened using a pre-determined inclusion and exclusion criteria.

3.2   Inclusion and Exclusion Criteria

3.2.1 Inclusion
Eligibility criteria looked at four key factors: (1) peer-reviewed articles published on or after year 2000 in any part of the world; gray literature published on or after 2000 by any government, international or multinational organization or agency; (2) the main theme(s) of the article address health security workforce research or relate to at least one of the following workforce focus areas: global health or public health workforce development framework or policy, global health workforce scope, pandemic preparedness, and response; (3) article focuses on national or global health security workforce; and (4)

published in English. English-based articles were included as an eligibility criterion due to language limitations of the reviewer.

This study included articles in English that discussed a combination of key concepts, including pandemic preparedness and response, global health security, workforce development, governance for global health, and health system strengthening, and literature examining political or social drivers and implications of health workforce development.

3.2.2 Exclusion

The study excluded articles that focused exclusively on medical health emergencies or global health policies and programs that were not specifically aligned to workforce development. Exclusion criteria included being

- published prior to 2000.

- not published in English.

To address the issue of bias in the study, country specific workforce development reports, international or institutional reports as well as after action review report on health workforce development were also excluded because they were neither peer reviewed nor linked with impact citation indices. Further they do not follow specific study design methodologies. However, cited published articles in these country and organizational specific reports were manually searched for inclusion.

3.3   Data collection and management

3.3.1 Data extraction

Searched results were screened and full text assessed for inclusion. Covidence tool [88], a web-based software platform was used to screen for title, abstract, and full-text screening.

Microsoft Excel™ was then used to extract as data extraction form to record information from the selected full-text literature. The form was developed based on the research objectives.

3.3.2 Data synthesis

Studies were analyzed to evaluate their relevance for inclusion, focusing on the following aspects: (i) objectives; (ii) key global health stakeholders; (iv) health profession; (v) competencies; and (vi) modalities for training. The gathered data were analyzed to provide initial answers to the research questions.

3.4   Institutional Review Board (IRB)

This study is a literature review and did not involve human subjects' research, therefore no IRB consideration was required.

CHAPTER FOUR

4.1   Findings

The literature search identified 1,431 articles that included the search terms: PubMed™

(n=74), Web of Science™ (n=609), and ERIC™ (n=748). (Fig 2)

Figure 2. PRISMA Diagram of Literature on Global Health Workforce Development,
   2020 – 2021
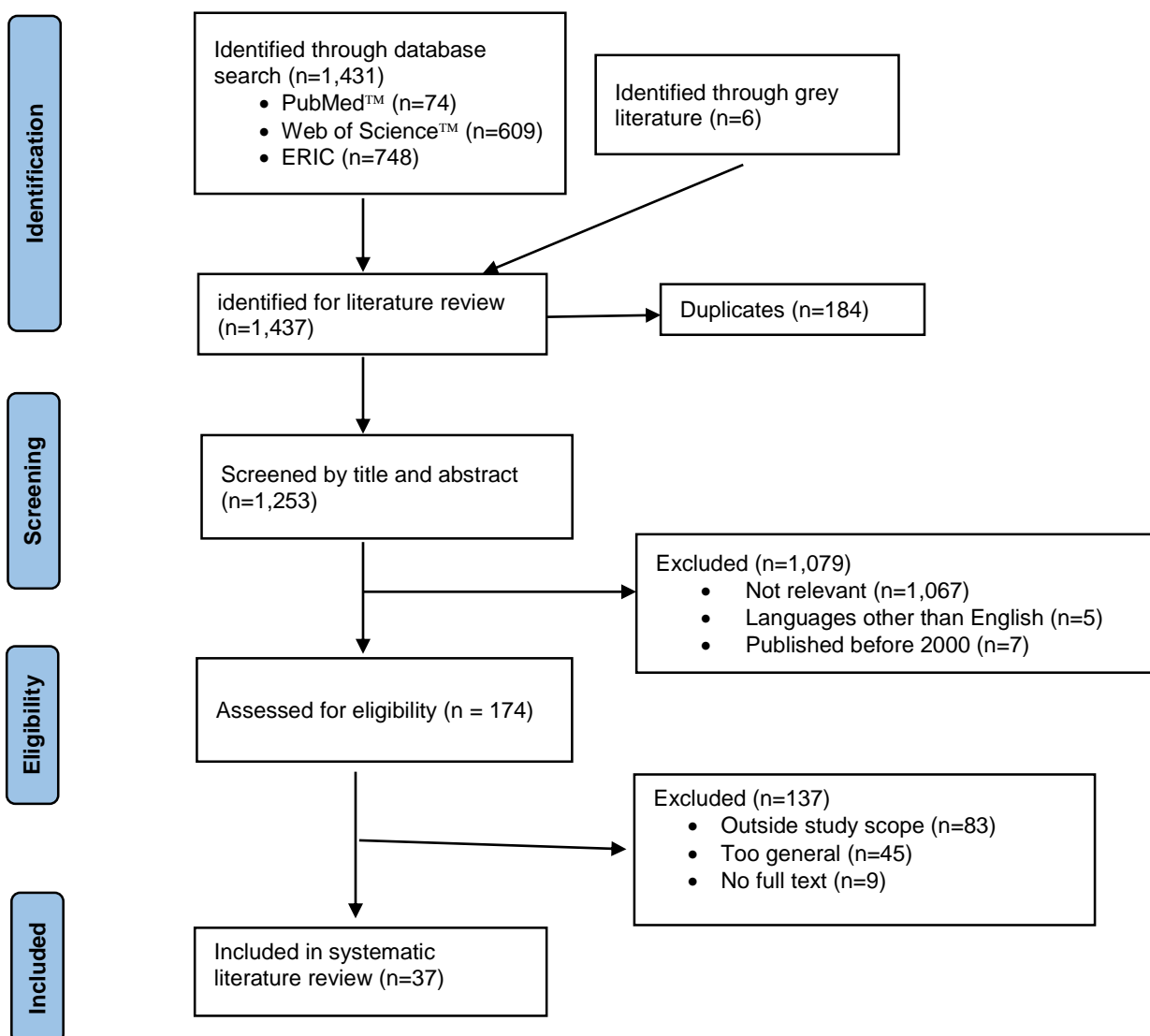
Grey literature from hand search using google and specific organization websites added six articles bringing the total number of articles to 1,437. After removing 184 duplicated from the search results, 1253 references remained for title and abstract screening. Among these, 1,079 articles were identified to be irrelevant due to exclusion criteria: not related to the study in any way (1,067), written in a language other than English (n=7), before 2,000 (n=5). Of the 174 that underwent full text review, 137 were excluded due to inclusion criteria: no full text available (9), too general or not focused on study objectives (n=45), outside study scope (n=83). The remaining 37 were considered relevant to the study objectives and therefore included in the study.

Key information from each of the 37 included articles were abstracted into an Excel database. These 37 articles were comprised of 31 empiric studies assessing global health workforce development specifically (n=23) or the public health workforce more generally but included specific information on workforce demand/enumeration (n= 9). Eleven studies described capacity building activities and five described specific training programs designed to enhance workforce development in governmental public health agencies. Four articles described the process of developing applied epidemiology competencies. Six articles were non-empiric in nature and were obtained from international organization and academic institutions that provided theoretical concepts and recommendations to the development of global health security workforce.

4.2   Publications on Global Health Workforce Development

The trend in publications on global health workforce development in this study showed the first five years of the 21st century did not record any publications on global health security workforce. (Fig 3)

Figure 3. Publication Trends on Global Health Workforce Development, 2000 – 2021
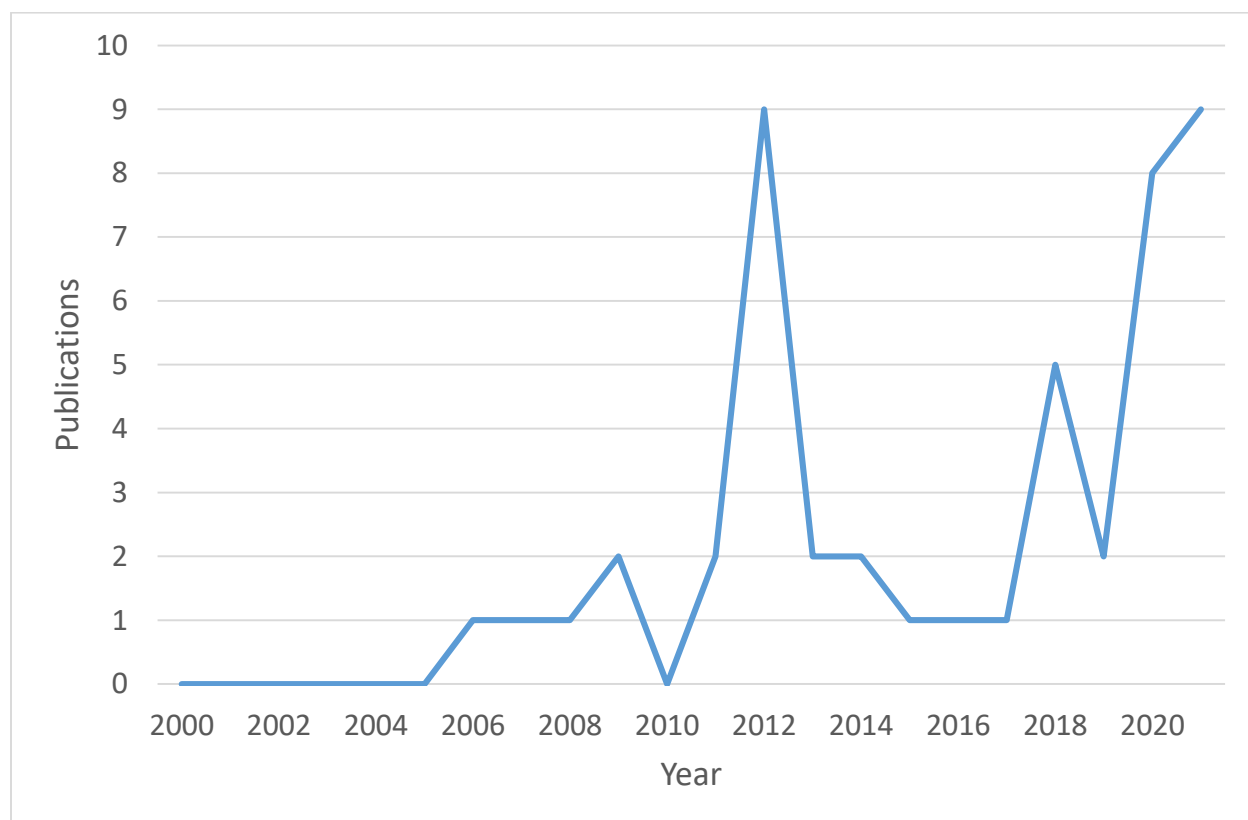
Approximately 1 publication per year were observed from 2006 until 2010. From 2011 to 2012, there was a significant increase, approximately 24.4% of articles included in the study. However, there was a sharp decrease in publications from 2012 until 2019 when there was a renewed interest in global health workforce. Majority, representing 45.9% of publications on global health workforce development were recorded between 2020 and 2021.

Figure 4. Geo-distribution of Publications on Global Health Workforce Development, by Continent, 2000 – 2021
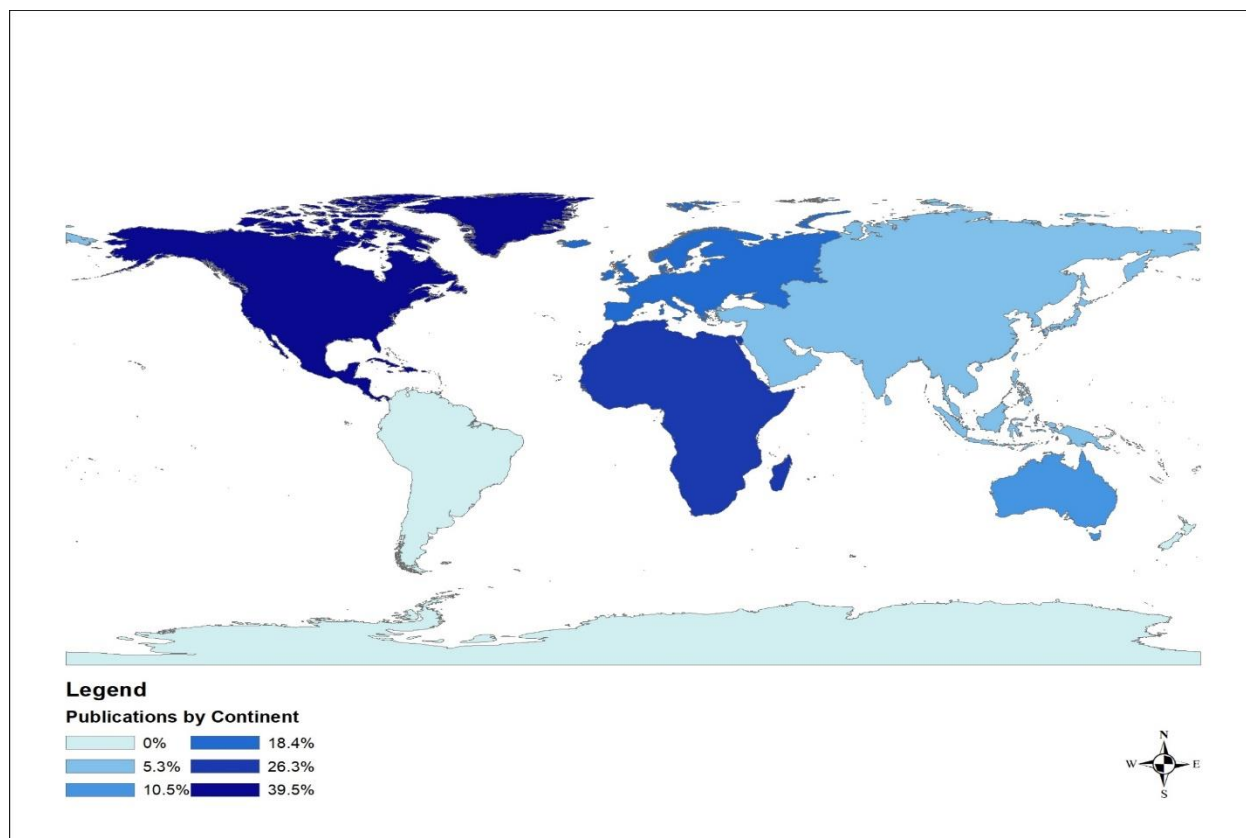
The geographic distribution of publications on Global Health Workforce Development in this study showed approximately 40% of publications on global health workforce development originated from North America, precisely the United States of America. (Fig 4) About 26% and 18 % of eligible publications on workforce development came from Africa and Europe respectively. Australia and Asia accounted for about 10% and 5% of publications respectively. Whereas most of these publications came from North America, there was no publication that originated from South America.

4.3   Existing frameworks for global health security workforce development

This section explored the key stakeholders and existing frameworks that guides global

health workforce development. Global health workforce development framework is

diverse and uniquely specific to different organizational context. Many organizations have

their unique frameworks that guide their workforce development programs. Twelve

frameworks were identified in the review.

Table 1. Workforce Development Frameworks identified in literature review,2000 – 2021

| Covidence#	Authors	Framework	Focus	Key Issues	Gaps
21	Bashkin *et* al., 2021	SEEPHI workforce development framework	Enhance the public health workforce in Israel through sharing European educational experience, including harmonization, employability, leadership, and outreach	Current and future professional roles and functions that comprise the national public health system must be identified and redefined; explicit description of competencies to identify potential skills gaps and inform the development of training and educational programs	Conceptual model yet to be implemented and evaluated
71	Williams *et* al., 2020	IHR/FETP	Monitoring and motivation for field epidemiology workforce capacity development	1 trained field epidemiologist (or equivalent) per 200,000 population; competency-based in-service training programs	No workforce development strategy; lack of explicit mention of competencies
86	Hung *et* al., 2021	Health EDRM workforce	Build workforce in risk management, emergency management, epidemic preparedness and response, community disaster resilience, and health systems strengthening	Planning for staff (e.g., surge capacity for emergency response including rapid response team; training for competency development; Occupational health and safety of personnel including community-level health workforce; protection of all workforce	Acknowledges significant gaps in identifying competencies for training and education and the lack of clarity on strategies for workforce retention, motivation, deployment, and coordination
140	Kumar *et* al., 2020	GHSA workforce development	Detect and respond to domestic and global public health threats in a timely way	One trained field epidemiologist per 200,000 population; national	Focused on epidemiologist and veterinary professions;

Covidence#	Authors	Framework	Focus	Key Issues	Gaps
				establishment of field epidemiology training programs	No specified workforce development strategy
153	Page, S; Willey, K, 2007	NCAHS workforce strategic framework	How workforce development plans can assist sustainable service delivery through targeted strategies in recruitment retention and retraining	The impact of workforce ageing, changes in case mix and population demographics; staff level guidelines associated with service enhancements, and changes in service delivery models	No clear strategy on health workforce enumeration to anticipate future demand; Health workforce is primarily limited to clinical staff
178	Naal 2020	Global health capacity building	Enhance the capabilities of individuals, organizations, and communities to work in or manage global health-related topics with special attention to LMIC in the MENA region	Increase access to education, training, mentoring, and continuous professional development; Expand the diversity and number of health professionals to effectively respond to global health threats	Vague on strategy for education, training and continuous professional development since no competencies identified
181	Richmond et al., 2014	Preparedness and Emergency Response Learning Centers (PERLCs)	To improve workforce readiness and competence through the development, delivery, and evaluation of targeted learning programs designed to meet specific requirements of state, local, and tribal partners in United States	Showcase a flexible, scalable, and experienced national learning system linking academia with practice; enhance individual, organizational, and community performance through the application of public health science and learning technologies to frontline practice	Lack training curriculum to guide workforce development across different competencies

Covidence#	Authors	Framework	Focus	Key Issues	Gaps
199	Kerry *et* al., 2020	Global health service partnership	U.S. government program to build human resource capacity for health in sub-Saharan African countries	Enhance health workforce through building partnership with health training institutions in host countries	Colonialist in outlook
N/A	WHO, 2009	Health systems strengthening and human resource development	Monitoring and evaluation of human resources for health in countries	Knowledge, skills, motivation and deployment of health workers; distribution and production of health workers	Acknowledges gaps in monitoring workforce demand and supply; biased towards clinical healthcare staff

4.4   Key stakeholders identified for Global Health Workforce Development

The main stakeholders identified in Global Health Workforce Development in this study

showed about a third of all publications identified government as the primary stakeholder

(Fig 5). The World Health Organization (19%) and the U.S. Centers for Disease Control

and Prevention (18%) were recognized as key stakeholders in workforce development.

Other stakeholders identified through literature include tertiary institutions (12%),

Regional Health Organizations such as Africa CDC, PAHO, etc. (10%). Although not

much attention was given to these organizations, the world organization for animal health,

OEI and the Food and Agricultural Organizations, FAO were also mentioned among

stakeholders required for global health security workforce development.

Figure 5. Stakeholders Supporting Global Health Workforce Development, 2000 –2021
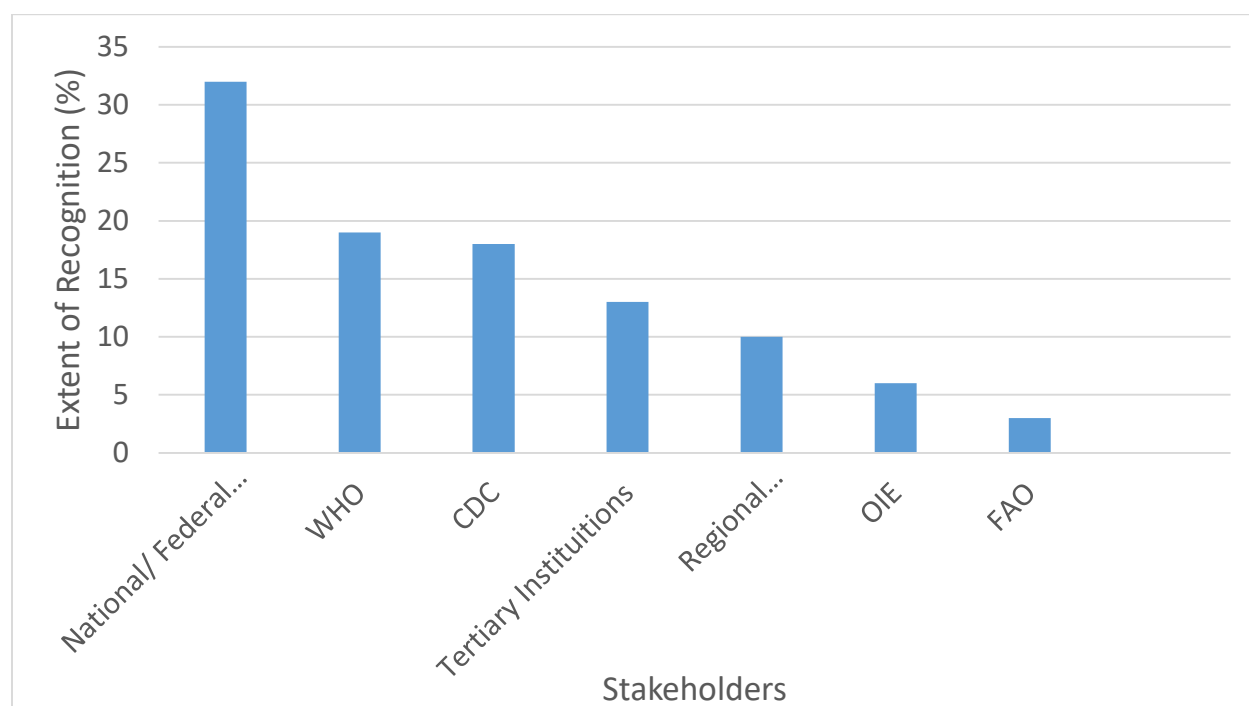
4.5   Composition of global health security workforce

This section explored the nuanced outlook on the various cadre of global health workforce. Articles that specifically focused on workforce development were reviewed to identify the different professions that constitute health workforce.

4.5.1   Key global health workforce

The main workforce identified as the backbone of global health security in this study showed public health physicians tallied 15 counts in all publications whereas epidemiologist and public health nurses tallied 13 respectively (Fig 6). Medical Laboratory staff tallied 8 in all the publications. Veterinary officers, community health workers, environmental health officers, informaticians or statisticians were randomly mentioned. Similarly, a host of other professionals were identified to play some role in ensuring global health security.

Figure 6: Health Professions Identified as Key for Global Health Security, 2000 – 2021
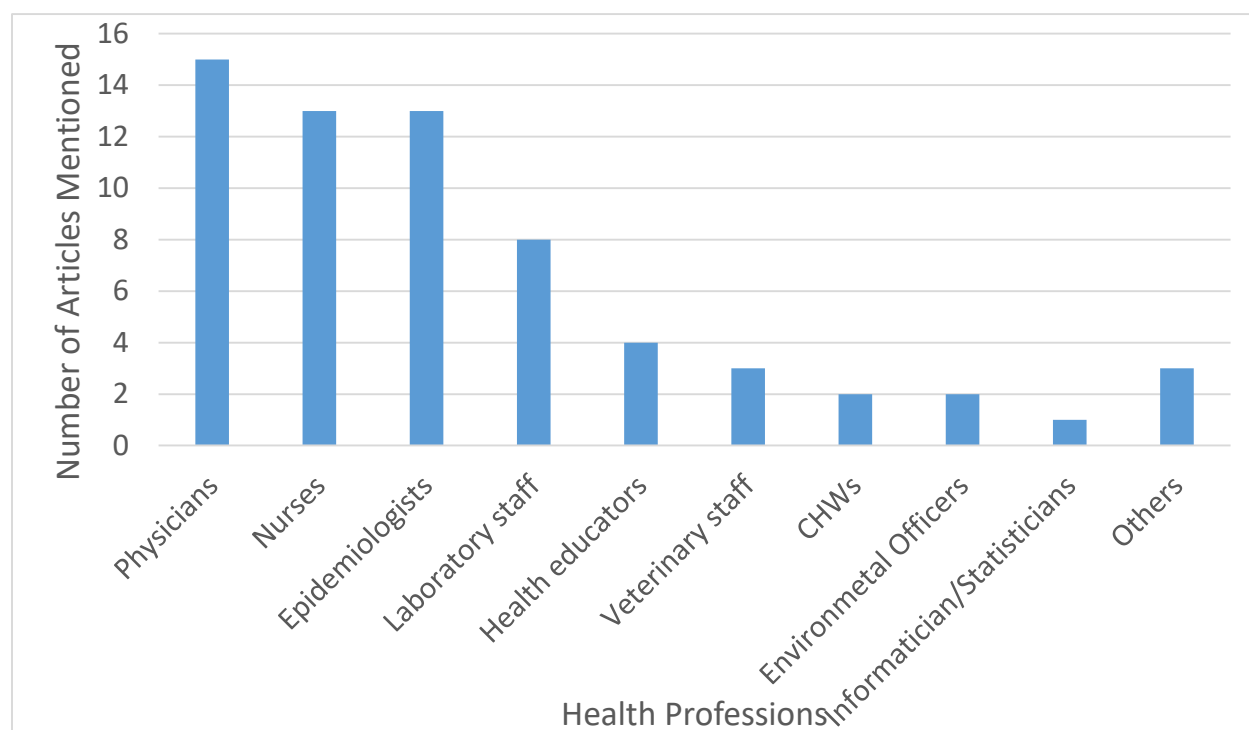
4.6 Monitoring global health workforce to anticipate demand

The articles that addressed Global Health workforce demand/enumeration in this study showed about 24% of all articles included in this study mentioned the importance of global health workforce demand and enumeration, only a few provided specific guidelines of workforce enumeration.

Table 2. Literature that aimed at Estimating Health Workforce Demand and Supply

Covidence#	Authors, year of publication	Objective(s)	Focus of interest	Specified Enumeration
1*	Beck, A. J., & Boulton, M. L. (2012)	Determine the size and composition of the workforce and how workforce can be monitored and demand projected	Health workforce in United States	No specific enumeration identified
46	Watts *et* al., 2020	Identify and explore research which has defined and enumerated public health workforces and how did researchers make judgments about the size of a workforce	Seven literature sources identified 11 national public health workforce estimates	Both the highest absolute estimate and estimate per 100,000 persons was for the United States with a total workforce of 326,602 (104.2 per 100,000) in 2012; Switzerland had the second highest workforce per 100,000 (102.6 per 100,000) in 2013, while Eritrea had the lowest number of workers per 100,000 was Eritrea [7.3 per 100,000 in 2015)
86	Hung *et* al., 2021	Effectively identify, mobilize, and manage all available human resources with different levels of skills, experiences, and knowledge	Developing effective health workforce strategies for low- and middle-income countries and high-income countries	Identified some cadre but no specific demand forecast for any category provided

Covidence#	Authors, year of publication	Objective(s)	Focus of interest	Specified Enumeration
218	Macharia *et* al., 2021	Evaluate the relationship between geographical changes in the number of Frontline FETP graduates and disease reporting across the 47 Kenyan counties	Developing a 3-month Frontline Field Epidemiology Training Program that targets local ministries of health to strengthen disease surveillance and reporting capacities in Kenya	Aside the findings that a total of 456 Frontline FELTP were trained from 2014 to 2017, that increased the numbers of epidemiologist by 700%. There was no specific health workforce demand forecasted

4.7   Global health workforce training modalities

Preferred modalities for workforce development or training programs showed a majority

of the articles reviewed (70.3%) did not specify the method for conducting workforce

development or training. (Table 3). For those that did, an overwhelming majority identified

the hybrid approach to training as more preferable in the transfer of skills and

competencies.

Table 3. Preferred Modalities for Health Workforce Development, by Published Articles,
2000 – 2021

Training Modality	Frequency	Percentage
− In person	2	5.4
− Online	0	0
− Hybrid	9	24.3
− Not specified	26	70.3

CHAPTER FIVE

5.1 Discussion

5.1.1 Publication trends on global health workforce development

The study results show three important timelines in the publications of literature on health workforce development were; 2006, 2012 -– 2013, and post- 2019. The first year to record literature on the topic was in 2006. This was immediately after the 2003 SARS pandemic and at the time that the World Health Assembly met to discuss revising the existing IHR. After this period, 2012 and 2013 saw a spike in workforce development literature. These periods coincide with when the world was recovering from the MERS pandemic, and also during the early stages of the Ebola pandemic in West Africa. Publications decreased after 2013 until around 2019 when there was renewed interest in global health workforce development as evidenced by the steady increase in literature from 2019 till end of this review period.

The observed publication trend on global health workforce development correlated with major global health events. It is evident that during or after a pandemic, there is global interest to build the capacity of the health workforce to mitigate the impact of the pandemic. However, it is obvious that this interest in health workforce wanes after the pandemic.

5.1.2 Geo-distribution of source literature

There is a near universal global interest in health workforce development. Majority of source literature came from North America in general and the United States, specifically. This confirms a similar study by DeVita *et* al., (2021) in a study that explored literature on how health providers are prepared for and respond to global emergencies around the globe. [89] The paper identified the United States as the source for most literature. Although

that paper found no source literature to emanate from Africa, this systematic review conversely identified Africa as next to North America in continents with most source literature on health workforce development.

The United States is the leading investor in health workforce development domestically and globally. The American Rescue Plan (ARP) devoted $7.66 billion to establishing, expanding, and sustaining the U.S. public health workforce[90]. In Fiscal Year (FY) 2021, the U.S. spent > $9 billion in global health programs, much to advance global health security and pandemic preparedness through the provision of assistance to better prevent, detect, and respond to infectious disease threats.

The finding highlighted the increasing contribution of African countries and academia towards global health workforce. Africa has been a major beneficiary of health workforce development programs. To complement external support, African governments in the last decade have increased national and regional financing for health, scientific research and health workforce capacity building.[91,92]Additionally, African universities and academicians continue to research innovative approach in health systems strengthening and workforce development.

5.1.3 Key stakeholders and existing frameworks

Building the capacity of health workforce to improve health outcomes to prevent, detect, and respond to global health threats requires diverse stakeholders working synergistically.[93,94] National governments as the main stakeholder responsible for health workforce development. This agrees with Lim and Lin (2021) who posit that health workforce *governance is an intrinsic responsibility of government policymaking.*[93] This viewpoint acknowledges government as the ultimate stakeholder responsible for overall

health workforce policy formulation and implementation. Similarly, the national government should take the lead in strategies aimed at health workforce development by engaging and bring all relevant stakeholders to the table.[95]

The World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention were identified as major stakeholders for workforce development. WHO is the largest international stakeholder and engages national Ministries of Health (MoH), Ministries of Finance, policy makers, international organizations, and philanthropic societies to support health systems strengthening (HSS) in low-and-middle income countries (LMICs). WHO actively support health workforce development as one of the core building blocks of the HSS framework. Similarly, the U.S. CDC through the Division of Global Health Protection (DGHP) supports national public health institutes train the workforce to prevent, detect, and respond to health threats.[68]

Surprisingly, the World Organization for Animal Health (OIE) and the Food and Agriculture Organizations (FAO) were identified as minor stakeholders. This finding contrasts the goals of the One Health concept which underscores the relationship between human, animal, and environmental health. Although there is an inter-connection between human, animal, and environmental health,[81,96,97] workforce development programs are usually skewed in favor of the human health component of the triad[98] thus, undermining holistic workforce development across these important disciplines.

The study also identified some workforce development frameworks and gaps in them (Table 1). The IHR/FETP and the GHSA workforce development frameworks were assessed to be non-specific with how to attain their objectives. The Global Health Service partnership (GHSP), relied on the United States to send physicians and nurses as faculty

at medical and nursing schools in low-resource countries to increase the quantity and quality of health graduates. This framework and similar ones aside reinforcing colonialism in global health, does not provide any guiding principles that underpins their operations. Specific workforce cadre, competencies and skillsets that need to be developed are not mentioned.

5.1.4   Composition of global health security workforce

Attainment of the goals of global health security depends on adequately staffed, highly skilled, and diverse cadre of health professionals. Enumerating the different health workforce has been a challenge among stakeholders. Although there are over 200 health professionals, only nine were actively identified and physicians, nurses, and epidemiologists were identified as the major professions relevant to global health security. Physicians and nurses were similarly identified as the main health workforce in the HSS framework [25], while on the other hand, the Global Health Security Agenda specifically focused on epidemiologists and laboratory personal as essential to global health security.[99] In general, healthcare workforce typically focus on physicians and nurses.[100]

There appear to be *bifurcated perspectives* on global health security which has not led to a clear definition for the global health security workforce [99]. Although the main agenda of the Oslo Declaration in 2007 was aimed at building the 'Capacity for global health security', no consensus existed as to what this phrase meant or who constituted the global health security workforce among government officials.[101] The lack of clarity on who constitute the health workforce has led to diverse approaches and inconsistencies in workforce competencies among different stakeholders and undermines workforce collaboration, capacity building, resource allocation, and accountability.

5.1.5 Monitoring the global health workforce to anticipate demand

An enumeration system for health workforce is necessary to assess whether workforce is large and skilled enough to meet health threats.[102] Knowing the composition, size, and demographic characteristics of health workforce is necessary for to planning, advocacy for additional resources, and to serve as tool for workforce accountability. Attempts at monitoring and enumerating workforce has been unsuccessful in most instances. Few literatures articles attempted to conduct study of health workforce enumeration with the aim to anticipate future demand[103–106]. Presently, there is no comprehensive methodologies to assess the adequacy of the health workforce to respond to health threats in a given population.[25]

The global health workforce is further plagued by an unclear definition of scope in terms of knowledge, expertise, and practice.[107] Thus, leading to a corresponding lack of clarity on the composition of the public health workforce.

5.1.6 Global health workforce training modalities

Public health is dynamic and subject to re(emerging) health threats, social mobility, and epidemiologic transitions. This requires a workforce to be effectively trained. Different modalities have been explored or used to train the health workforce acquire specific competencies or build on existing expertise. Most literature reviewed did not specify a particular format. Failure to identify an effective format undermines the quality of literature seeking to advocate for global health workforce development. Among the few articles that addressed modalities, the overwhelming majority identified the hybrid format; it combines online (web-based technology) and in person learning methodologies as more effective at building the competencies of workforce. According to one of the studies reviewed,

health workforce also preferred hands-on or "learning by doing" approach that makes it easier for them to gain practical skills and apply expected competencies at their respective workplaces.[108]

In a study conducted in New South Wales for public health professionals to access preferred modalities for workforce development, participants noted that they liked receiving training at their worksite. Participant expressed interest in online learning which gave them the flexibility to engage with learning modules at their own pace. However, they did not like the technical challenges such as poor sound quality and internet connectivity associated with online/web training.[109] Blended, problem-based learning might be an effective and efficient way to develop and transfer competencies among public health professionals in international and interdisciplinary context.[110] Barriers to such an approach must be taken in perspective.

5.2 Conclusion

We identified 37 articles that focused on developing the global health workforce between 2000 and 2021. The aim was to identify different stakeholders and frameworks that support global health workforce development and the gaps in them. In addition, this study aimed to assess how health workforce was enumerated to make projections for demand.

Our findings suggested there is universal interest in global health workforce development particularly during and immediately after major global health events, although this interest ebbs after the health event. The study showed that there is an increase in workforce development activities in Africa over the period.

Many studies identified national governments as primary stakeholder for health workforce development. They concluded that national governments should take the lead in building

the capacity of health workforce through human and financial investment among other strategies. The WHO and the U.S. CDC were identified as major international stakeholders that complement national governments in health workforce development. Considering the interconnectedness between human, animal, and environment health, One Health was initiated to collaboration, communicate, and coordinate among them to prevent, detect, and respond to health threats. However, the study noted that the organization for animal health (OIE) and the food and agriculture organization (FAO) were minor stakeholders. This undermined the aims of One Health for global health security.

Our study identified physicians, nurses, epidemiologists, and laboratory personnel as the main health workforce cadre. However, most studies failed to take current developments such synthetic biology, artificial intelligence, climate change and their impacts on health security into consideration. The study identified that due to lack of a clear definition of global health security workforce, enumeration has been challenging. Identifying global health workforce was mostly based on the traditional health professional nomenclature, that led to uneven allocation of resources and workforce development capacities.

While most studies did not specify any modality for conducting training for workforce, there was a general preference for the hybrid format that incorporated in-person and online platforms for training. The study identified that combining in-person training ensures that workforce can get practical experience with developing certain competencies. Online platforms also allow flexibility for workforce to build on other competencies that does not require travelling long distances.

5.3   Strengths and Limitations

This systematic literature review was restricted between Jan 2000 and Dec 2001. The study may have missed relevant literature published prior to 2000. This potentially missed literature that could have provided additional information to support or alter the findings of this study. Again, because of the limitation of language, only literature published in English were selected for review. Important source not published in English may have been missed. Finally, the review was conducted by a single researcher whose personal opinions and beliefs may have biased the selection of articles, analysis and presentation of findings in this study. To mitigate the impact of these limitations, the study protocol was rigorously followed. The transparency of the methodology and search strategy enhance the replicability of this study.

5.4   Recommendations

The following recommendations are made to modernize approaches to global health workforce development to prevent, detect, and respond to re(emerging) health threats.

Global health security stakeholders (WHA, WHO, GHSA, FAO, OIE) should clearly define global health security and the professions constituting the global health security workforce. A clearly defined workforce will ensure that capacity building opportunities, financial, logistics, and other necessary resources are targeted. Stakeholders should consider current advances in biotechnology such as synthetic biology, the Do-It-Yourself (DIY) community, bioterrorism, biosecurity, and biosafety concerns into the holistic review of global health security and workforce.

Global health stakeholders should ensure sustained efforts at workforce development. Frameworks for global health security such as the IHR or GHSA that in part addresses workforce development should be specific with indicators and competencies expected of the cadre of health workforce. Workforce should be engaged through competency-based in-service training, retraining, and cross-training using a hybrid modality of in-person and online.

Finally, there is the need for additional training in general skills related to leadership and working in multidisciplinary teams. One Health should be actively pursued to ensure that health workforce across human, animal and the environmental disciplines can collaborate, exchange information and best practices towards the prevention, detection and response to global health threats.

REFERENCES

1. Priyadarsini SL, Suresh M, Huisingh D. What can we learn from previous pandemics to reduce the frequency of emerging infectious diseases like COVID-19? *Global Transitions*. 2020;2:202-220. doi:10.1016/j.glt.2020.09.003

2. Wei J, Hansen A, Zhang Y, et al. The impact of climate change on infectious disease transmission: perceptions of CDC health professionals in Shanxi Province, China. *PLoS One*. 2014;9(10):e109476. doi:10.1371/journal.pone.0109476

3. Xiong J, Lipsitz O, Nasri F, et al. Impact of COVID-19 pandemic on mental health in the general population: A systematic review. *J Affect Disord*. 2020;277:55-64. doi:10.1016/j.jad.2020.08.001

4. Alba SA and F. The unemployment impacts of COVID-19: lessons from the Great Recession. Brookings. Published April 15, 2020. Accessed April 5, 2022. https://www.brookings.edu/blog/up-front/2020/04/15/the-unemployment-impacts-of-covid-19-lessons-from-the-great-recession/

5. Madhav N, Oppenheim B, Gallivan M, Mulembakani P, Rubin E, Wolfe N. Pandemics: Risks, Impacts, and Mitigation. In: Jamison DT, Gelband H, Horton S, et al., eds. *Disease Control Priorities: Improving Health and Reducing Poverty*. 3rd ed. The International Bank for Reconstruction and Development / The World Bank; 2017. Accessed April 5, 2022. http://www.ncbi.nlm.nih.gov/books/NBK525302/

6. OECD. *Strengthening Health Systems during a Pandemic: The Role of Development Finance*.; 2020. doi:10.1787/f762bf1c-en

7. Moodie A, Gerami N, D'Alessandra F. Rethinking Health Security after COVID-19. Published online November 2021. Accessed April 5, 2022. https://www.bsg.ox.ac.uk/research/publications/rethinking-health-security-after-covid-19

8. Tulenko K, Vervoort D. Cracks in the System: The Effects of the Coronavirus Pandemic on Public Health Systems. *The American Review of Public Administration*. 2020;50(6-7):455-466. doi:10.1177/0275074020941667

9. Kuhlmann E, Dussault G, Correia T. Global health and health workforce development: what to learn from COVID-19 on health workforce preparedness and resilience. *Int J Health Plann Manage*. 2021;36(S1):5-8. doi:10.1002/hpm.3160

10. Kluge H, Martín-Moreno JM, Emiroglu N, et al. Strengthening global health security by embedding the International Health Regulations requirements into national health systems. *BMJ Glob Health*. 2018;3(Suppl 1):e000656. doi:10.1136/bmjgh-2017-000656

11.   World Health Organisation. International Health Regulations (2005) Third Edition. Published 2005. Accessed February 16, 2022. https://www.who.int/publications/i/item/9789241580496

12.   Burwell SM, Townsend FF, Bollyky TJ, Patrick SM. The U.S. Must Learn From COVID-19 to Prevent the Next Disaster. Council on Foreign Relations. Published 2020. Accessed February 16, 2022. https://www.cfr.org/report/pandemic-preparedness-lessons-COVID-19/

13.   Hassell JM, Begon M, Ward MJ, Fèvre EM. Urbanization and Disease Emergence: Dynamics at the Wildlife–Livestock–Human Interface. *Trends Ecol Evol*. 2017;32(1):55-67. doi:10.1016/j.tree.2016.09.012

14.   Jones BA, Grace D, Kock R, et al. Zoonosis emergence linked to agricultural intensification and environmental change. *Proc Natl Acad Sci U S A*. 2013;110(21):8399-8404. doi:10.1073/pnas.1208059110

15.   Pedersen AB, Davies TJ. Cross-Species Pathogen Transmission and Disease Emergence in Primates. *Ecohealth*. 2009;6(4):496-508. doi:10.1007/s10393-010-0284-3

16.   Schneider MC, Munoz-Zanzi C, Min K duk, Aldighieri S. "One Health" From Concept to Application in the Global World. Oxford Research Encyclopedia of Global Public Health. doi:10.1093/acrefore/9780190632366.013.29

17.   Dalglish SL. COVID-19 gives the lie to global health expertise. *The Lancet*. 2020;395(10231):1189. doi:10.1016/S0140-6736(20)30739-X

18.   Hale T, Angrist N, Goldszmidt R, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat Hum Behav*. 2021;5(4):529-538. doi:10.1038/s41562-021-01079-8

19.   Wolff S, Ladi S. European Union Responses to the Covid-19 Pandemic: adaptability in times of Permanent Emergency. *Journal of European Integration*. 2020;42(8):1025-1040. doi:10.1080/07036337.2020.1853120

20.   CDC. 2009 H1N1 Pandemic. Centers for Disease Control and Prevention. Published June 11, 2019. Accessed December 19, 2021. https://www.cdc.gov/flu/pandemic-resources/2009-h1n1-pandemic.html

21.   World Health Organization. Middle East respiratory syndrome coronavirus (MERS-CoV). Published 2019. Accessed April 5, 2022. https://www.who.int/health-topics/middle-east-respiratory-syndrome-coronavirus-mers

22.   Coltart CEM, Lindsey B, Ghinai I, Johnson AM, Heymann DL. The Ebola outbreak, 2013–2016: old lessons for new epidemics. *Philos Trans R Soc Lond B Biol Sci*. 2017;372(1721):20160297. doi:10.1098/rstb.2016.0297

23. JHU. COVID-19 Map. Johns Hopkins Coronavirus Resource Center. Published 2021. Accessed November 24, 2021. https://coronavirus.jhu.edu/map.html

24. World Health Organization. *Global Strategy on Human Resources for Health: Workforce 2030*. World Health Organization; 2016. https://apps.who.int/iris/handle/10665/250368

25. World Health Organization. *Monitoring the Building Blocks of Health Systems: A Handbook of Indicators and Their Measurement Strategies*. World Health Organization; 2010. Accessed November 26, 2021. https://apps.who.int/iris/handle/10665/258734

26. Keeley C, Jimenez J, Jackson H, et al. Staffing Up For The Surge: Expanding The New York City Public Hospital Workforce During The COVID-19 Pandemic. *Health Aff (Millwood)*. 2020;39(8):1426-1430. doi:10.1377/hlthaff.2020.00904

27. McNabb SJN Conde, Marc J, Ferland, Lisa,. *Transforming Public Health Surveillance : Proactive Measures for Prevention, Detection, and Response*.; 2016.

28. Tromberg BJ, Schwetz TA, Pérez-Stable EJ, et al. Rapid Scaling Up of Covid-19 Diagnostic Testing in the United States - The NIH RADx Initiative. *N Engl J Med*. 2020;383(11):1071-1077. doi:10.1056/NEJMsr2022263

29. Bignardi G, Dalmaijer ES, Anwyl-Irvine AL, et al. Longitudinal increases in childhood depression symptoms during the COVID-19 lockdown. *Arch Dis Child*. Published online December 9, 2020:archdischild-2020-320372. doi:10.1136/archdischild-2020-320372

30. Panchal U, Salazar de Pablo G, Franco M, et al. The impact of COVID-19 lockdown on child and adolescent mental health: systematic review. *Eur Child Adolesc Psychiatry*. Published online August 18, 2021. doi:10.1007/s00787-021-01856-w

31. Huber C, Finelli L, Stevens W. The Economic and Social Burden of the 2014 Ebola Outbreak in West Africa. *J Infect Dis*. 2018;218(suppl_5):S698-S704. doi:10.1093/infdis/jiy213

32. Cutler DM, Summers LH. The COVID-19 Pandemic and the $16 Trillion Virus. *JAMA*. 2020;324(15):1495-1496. doi:10.1001/jama.2020.19759

33. Donthu N, Gustafsson A. Effects of COVID-19 on business and research. *Journal of Business Research*. 2020;117:284-289. doi:10.1016/j.jbusres.2020.06.008

34. Buheji M, da Costa Cunha K, Beka G, et al. The Extent of COVID-19 Pandemic Socio-Economic Impact on Global Poverty. A Global Integrative Multidisciplinary Review. *economics*. 2020;10(4):213-224. doi:10.5923/j.economics.20201004.02

35. Gupta J. What does coronavirus mean for violence against women? - Women's Media Center. Published 2020. Accessed November 25, 2021. https://womensmediacenter.com/news-features/what-does-coronavirus-mean-for-violence-against-women

36. UN Women. COVID-19 and ending violence against women and girls. UN Women. Published 2020. Accessed February 16, 2022. https://www.unwomen.org/en/digital-library/publications/2020/04/issue-brief-covid-19-and-ending-violence-against-women-and-girls

37. Singh S, Roy D, Sinha K, Parveen S, Sharma G, Joshi G. Impact of COVID-19 and lockdown on mental health of children and adolescents: A narrative review with recommendations. *Psychiatry Res*. 2020;293:113429. doi:10.1016/j.psychres.2020.113429

38. UNESCO. UNESCO figures show two thirds of an academic year lost on average worldwide due to Covid-19 school closures. UNESCO. Published 2021. Accessed December 9, 2021. https://en.unesco.org/news/unesco-figures-show-two-thirds-academic-year-lost-average-worldwide-due-covid-19-school

39. Garcia E, Weiss E. COVID-19 and student performance, equity, and U.S. education policy: Lessons from pre-pandemic research to inform relief, recovery, and rebuilding | Economic Policy Institute. Published September 10, 2020. Accessed January 11, 2022. https://www.epi.org/publication/the-consequences-of-the-covid-19-pandemic-for-education-performance-and-equity-in-the-united-states-what-can-we-learn-from-pre-pandemic-research-to-inform-relief-recovery-and-rebuilding/

40. Pereda N, Díaz-Faes DA. Family violence against children in the wake of COVID-19 pandemic: a review of current perspectives and risk factors. *Child and Adolescent Psychiatry and Mental Health*. 2020;14(1):40. doi:10.1186/s13034-020-00347-1

41. Núñez A, Sreeganga SD, Ramaprasad A. Access to Healthcare during COVID-19. *Int J Environ Res Public Health*. 2021;18(6):2980. doi:10.3390/ijerph18062980

42. WHO. A World at Risk : Annual report on global preparedness for health emergencies - Global Preparedness Monitoring Board [EN/AR/RU/ZH] - World. ReliefWeb. Published 2019. Accessed December 9, 2021. https://reliefweb.int/report/world/world-risk-annual-report-global-preparedness-health-emergencies-global-preparedness

43. Maxmen A. Has COVID taught us anything about pandemic preparedness? *Nature*. 2021;596(7872):332-335. doi:10.1038/d41586-021-02217-y

44. Kandel N, Chungong S, Omaar A, Xing J. Health security capacities in the context of COVID-19 outbreak: an analysis of International Health Regulations annual

report data from 182 countries. *Lancet*. 2020;395(10229):1047-1053. doi:10.1016/S0140-6736(20)30553-5

45. Leavell S, Clark E G. Medicina Preventica: McGrow Hill. Published online 1976.

46. Czeresnia D. The concept of health and the difference between prevention and promotion. *Cad Saúde Pública*. 1999;15:701-709. doi:10.1590/S0102-311X1999000400004

47. Jones KE, Patel NG, Levy MA, et al. Global trends in emerging infectious diseases. *Nature*. 2008;451(7181):990-993. doi:10.1038/nature06536

48. Machalaba C, Romanelli C, Stoett P, et al. Climate Change and Health: Transcending Silos to Find Solutions. *Annals of Global Health*. 2015;81(3):445-458. doi:10.1016/j.aogh.2015.08.002

49. GOSTIN LO, KATZ R. The International Health Regulations: The Governing Framework for Global Health Security. *Milbank Q*. 2016;94(2):264-313. doi:10.1111/1468-0009.12186

50. Houghton C, Meskell P, Delaney H, et al. Barriers and facilitators to healthcare workers' adherence with infection prevention and control (IPC) guidelines for respiratory infectious diseases: a rapid qualitative evidence synthesis. *Cochrane Database of Systematic Reviews*. 2020;(4). doi:10.1002/14651858.CD013582

51. REYNOLDS B, W. SEEGER M. Crisis and Emergency Risk Communication as an Integrative Model. *Journal of Health Communication*. 2005;10(1):43-55. doi:10.1080/10810730590904571

52. Roderico H Ofrin, Nilesh Buddha, Maung Maung Htike, Anil K Bhola, Supriya Bezbaruah. Strengthening risk communication systems for public health emergencies in the WHO South-East Asia Region. *WHO South-East Asia Journal of Public Health*. 2020;9(1):15-20.

53. Institute of Medicine (US) Forum on Microbial. *Summary and Assessment*. National Academies Press (US); 2007. Accessed December 10, 2021. https://www.ncbi.nlm.nih.gov/books/NBK52862/

54. van Boheemen S, de Graaf M, Lauber C, et al. Genomic characterization of a newly discovered coronavirus associated with acute respiratory distress syndrome in humans. *mBio*. 2012;3(6):e00473-12. doi:10.1128/mBio.00473-12

55. Gwee SXW, Chua PEY, Wang MX, Pang J. Impact of travel ban implementation on COVID-19 spread in Singapore, Taiwan, Hong Kong and South Korea during the early phase of the pandemic: a comparative study. *BMC Infectious Diseases*. 2021;21(1):799. doi:10.1186/s12879-021-06449-1

56. Atalan A. Is the lockdown important to prevent the COVID-19 pandemic? Effects on psychology, environment and economy-perspective. *Annals of Medicine and Surgery*. 2020;56:38-42. doi:10.1016/j.amsu.2020.06.010

57. Aleta A, Martín-Corral D, Pastore y Piontti A, et al. Modelling the impact of testing, contact tracing and household quarantine on second waves of COVID-19. *Nat Hum Behav*. 2020;4(9):964-971. doi:10.1038/s41562-020-0931-9

58. CDC. Health Departments. Centers for Disease Control and Prevention. Published February 11, 2020. Accessed January 21, 2022. https://www.cdc.gov/coronavirus/2019-ncov/php/principles-contact-tracing.html

59. Patel S. Public Health Emergency Operations Coordination: Findings from After Action Reports and Case Reports. Published online 2019:28.

60. Olu OO, Lamunu M, Chimbaru A, et al. Incident Management Systems Are Essential for Effective Coordination of Large Disease Outbreaks: Perspectives from the Coordination of the Ebola Outbreak Response in Sierra Leone. *Frontiers in Public Health*. 2016;4. Accessed January 21, 2022. https://www.frontiersin.org/article/10.3389/fpubh.2016.00254

61. Davis XM, Rouse EN, Stampley C. Preparing the CDC Public Health Workforce for Emergency Response. *Journal of Homeland Security and Emergency Management*. 2021;18(1):1-21. doi:10.1515/jhsem-2019-0021

62. Parry AE, Kirk MD, Durrheim DN, Olowokure B, Colquhoun SM, Housen T. Shaping applied epidemiology workforce training to strengthen emergency response: a global survey of applied epidemiologists, 2019–2020. *Human Resources for Health*. 2021;19(1):58. doi:10.1186/s12960-021-00603-1

63. Morens DM, Fauci AS. Emerging Pandemic Diseases: How We Got to COVID-19. *Cell*. 2020;182(5):1077-1092. doi:10.1016/j.cell.2020.08.021

64. World Health Assembly 56. *Severe Acute Respiratory Syndrome (SARS)*. World Health Organization; 2003. Accessed December 21, 2021. https://apps.who.int/iris/handle/10665/78337

65. WHO. WHO | The World Health Report 2006. Working together for health. WHO. Published April 2006. Accessed December 11, 2021. https://www.who.int/workforcealliance/knowledge/resources/whreport_2006/en/

66. GHSA. Global Health Security Agenda | Strengthening Health Security Across the Globe: Progress and Impact of U.S. Government Investments in the Global Health Security Agenda - 2019 Annual Report - World. ReliefWeb. Published 2019. Accessed April 6, 2022. https://reliefweb.int/report/world/global-health-security-agenda-strengthening-security-across-globe-progress-and

67. GHSA. Workforce Development. Global Health Security Agenda. Published June 17, 2020. Accessed April 6, 2022. https://ghsagenda.org/workforce-development/

68. US Centers for Disease Control and Prevention. Workforce Development | Division of Global Health Protection | Global Health | CDC. Published December 21, 2021. Accessed March 23, 2022. https://www.cdc.gov/globalhealth/healthprotection/topics/workforce-development.html

69. CDC. Field Epidemiology Training Program (FETP) | Division of Global Health Protection | Global Health | CDC. Published June 3, 2021. Accessed December 11, 2021. https://www.cdc.gov/globalhealth/healthprotection/fetp/index.htm

70. GIBACHT Consortium. GIBACHT Consortium - Objectives of the training programme. Published 2021. Accessed December 11, 2021. http://www.gibacht.org/what-is-gibacht/objectives-of-the-training-programme/

71. Rohr JR, Barrett CB, Civitello DJ, et al. Emerging human infectious diseases and the links to global food production. *Nat Sustain*. 2019;2(6):445-456. doi:10.1038/s41893-019-0293-3

72. Watts N, Amann M, Arnell N, et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *The Lancet*. 2021;397(10269):129-170. doi:10.1016/S0140-6736(20)32290-X

73. Cavicchioli R, Ripple WJ, Timmis KN, et al. Scientists' warning to humanity: microorganisms and climate change. *Nat Rev Microbiol*. 2019;17(9):569-586. doi:10.1038/s41579-019-0222-5

74. WHO. Climate change and health. Published 2021. Accessed December 13, 2021. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

75. Li J, Zhao H, Zheng L, An W. Advances in Synthetic Biology and Biosafety Governance. *Front Bioeng Biotechnol*. 2021;9:598087. doi:10.3389/fbioe.2021.598087

76. Chen MY, Butler SS, Chen W, Suh J. Physical, chemical, and synthetic virology: Reprogramming viruses as controllable nanodevices. *Wiley Interdiscip Rev Nanomed Nanobiotechnol*. 2019;11(3):e1545. doi:10.1002/wnan.1545

77. Dunlap G, Pauwels E. Intelligent and connected bio-labs –promise and peril in the Fourth Industrial Revolution. World Economic Forum. Published October 2017. Accessed December 13, 2021. https://www.weforum.org/agenda/2017/10/intelligent-and-connected-bio-labs-promise-and-peril-in-the-fourth-industrial-revolution/

78. Cutler SJ, Fooks AR, van der Poel WHM. Public Health Threat of New, Reemerging, and Neglected Zoonoses in the Industrialized World. *Emerg Infect Dis*. 2010;16(1):1-7. doi:10.3201/eid1601.081467

79. Rozenbaum M. The increase in zoonotic diseases: the WHO, the why and the when? Understanding Animal Research. Published 2020. Accessed January 21, 2022. https://www.understandinganimalresearch.org.uk/news/research-medical-benefits/the-increase-in-zoonotic-diseases-the-who-the-why-and-the-when/

80. CDC. One Health Basics | One Health | CDC. Published October 15, 2020. Accessed January 21, 2022. https://www.cdc.gov/onehealth/basics/index.html

81. Carabin H. One Health: A crucial approach to preventing and preparing for future pandemics. The Conversation. Published 2021. Accessed January 21, 2022. http://theconversation.com/one-health-a-crucial-approach-to-preventing-and-preparing-for-future-pandemics-173637

82. Rasheed MA. Navigating the violent process of decolonisation in global health research: a guideline. *The Lancet Global Health*. 2021;9(12):e1640-e1641. doi:10.1016/S2214-109X(21)00440-X

83. Abimbola S. On the meaning of global health and the role of global health journals. *Int Health*. 2018;10(2):63-65. doi:10.1093/inthealth/ihy010

84. Dussault G, Franceschini MC. Not enough there, too many here: understanding geographical imbalances in the distribution of the health workforce. *Hum Resour Health*. 2006;4(1):12. doi:10.1186/1478-4491-4-12

85. Khan KS, Kunz R, Kleijnen J, Antes G. Five steps to conducting a systematic review. *J R Soc Med*. 2003;96(3):118-121.

86. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med*. 2018;169(7):467-473. doi:10.7326/M18-0850

87. Crawford CAG, Summerfelt WT, Roy K, Chen ZA, Meltzer DO, Thacker SB. Perspectives on public health workforce research. *J Public Health Manag Pract*. 2009;15(6 Suppl):S5-S15. doi:10.1097/PHH.0b013e3181bdff7d

88. Covidence System. Covidence - Better systematic review management. Covidence. Published January 29, 2022. Accessed January 29, 2022. https://www.covidence.org/

89. DeVita T, Brett-Major D, Katz R. How are healthcare provider systems preparing for health emergency situations? *World Med Health Policy*. Published online May 11, 2021:10.1002/wmh3.436. doi:10.1002/wmh3.436

90. American Hospital Association. Summary of American Rescue Plan Act of 2021 and Provisions Affecting Hospitals and Health Systems | AHA. Published March 2021. Accessed April 15, 2022. https://www.aha.org/advisory/2021-03-17-summary-american-rescue-plan-act-2021-and-provisions-affecting-hospitals-and

91. Laabes EP, Desai R, Zawedde SM, Glew RH. How much longer will Africa have to depend on western nations for support of its capacity-building efforts for biomedical research? *Trop Med Int Health*. 2011;16(3):258-262. doi:10.1111/j.1365-3156.2010.02709.x

92. R&D Data Release. Published June 28, 2018. Accessed March 23, 2022. http://uis.unesco.org/en/news/rd-data-release

93. Lim MYH, Lin V. Governance in health workforce: how do we improve on the concept? A network-based, stakeholder-driven approach. *Human Resources for Health*. 2021;19(1):1. doi:10.1186/s12960-020-00545-0

94. Teter W. Fostering problem driven collaboration in a development context: The ASEAN study of health workforce governance. *Asia Pacific Journal of Public Administration*. 2020;42(2):89-110. doi:10.1080/23276665.2020.1753222

95. Beck AJ, Spetz J, Pittman P, et al. Investing In A 21st Century Health Workforce: A Call For Accountability | Health Affairs Forefront. Published September 15, 2021. Accessed March 23, 2022. https://www.healthaffairs.org/do/10.1377/forefront.20210913.133585/full/

96. Cassidy A. *Humans, Other Animals and 'One Health' in the Early Twenty-First Century*. Palgrave Macmillan; 2017. doi:10.1007/978-3-319-64337-3_6

97. Acharya KP, Karki S, Shrestha K, Kaphle K. One health approach in Nepal: Scope, opportunities and challenges. *One Health*. 2019;8:100101. doi:10.1016/j.onehlt.2019.100101

98. Kahn LH. The Challenges of Implementing One Health. ISGP. Published 2015. Accessed March 23, 2022. http://scienceforglobalpolicy.org/publication/the-challenges-of-implementing-one-health/

99. Herrmann J, Blumenstock JS. Global health security: training a public health workforce to combat international and domestic threats. *J Public Health Manag Pract*. 2014;20 Suppl 5:S118-119. doi:10.1097/PHH.0000000000000105

100. Bashkin O, Dopelt K, Mor Z, et al. The Future Public Health Workforce in a Changing World: A Conceptual Framework for a European–Israeli Knowledge Transfer Project. *Int J Environ Res Public Health*. 2021;18(17):9265. doi:10.3390/ijerph18179265

101. Kamradt-Scott A. Global Health Security and Its Discontents. In: Kamradt-Scott A, ed. *Managing Global Health Security: The World Health Organization and*

Disease Outbreak Control. Palgrave Macmillan UK; 2015:151-179. doi:10.1057/9781137520166_7

102. Gebbie KM, Raziano A, Elliott S. Public Health Workforce Enumeration. *Am J Public Health*. 2009;99(5):786-787. doi:10.2105/AJPH.2008.137539

103. Beck AJ, Boulton ML. Building an effective workforce: a systematic review of public health workforce literature. *Am J Prev Med*. 2012;42(5 Suppl 1):S6-16. doi:10.1016/j.amepre.2012.01.020

104. Hung KKC, Mashino S, Chan EYY, et al. Health Workforce Development in Health Emergency and Disaster Risk Management: The Need for Evidence-Based Recommendations. *IJERPH*. 2021;18(7):3382. doi:10.3390/ijerph18073382

105. Macharia D, Jinnai Y, Hirai M, et al. Impact of Kenya's Frontline Epidemiology Training Program on Outbreak Detection and Surveillance Reporting: A Geographical Assessment, 2014-2017. *Health Secur*. 2021;19(3):243-253. doi:10.1089/hs.2020.0042

106. Watts RD, Bowles DC, Ryan E, Fisher C, Li IW. No Two Workforces Are the Same: A Systematic Review of Enumerations and Definitions of Public Health Workforces. *Front Public Health*. 2020;8:588092. doi:10.3389/fpubh.2020.588092

107. Sumaya CV. Enumeration and Composition of the Public Health Workforce: Challenges and Strategies. *Am J Public Health*. 2012;102(3):469-474. doi:10.2105/AJPH.2011.300388

108. Archer A, Berry I, Bajwa U, Kalda R, Di Ruggiero E. Evidence synthesis - Preferred modalities for delivering continuing education to the public health workforce: a scoping review. *Health Promot Chronic Dis Prev Can*. 2020;40(4):116-125.

109. Naylor CJ, Madden DL. Communication Technology Supporting the Public Health Workforce in New South Wales. *NSW Public Health Bull*. 2009;20(2):1. doi:10.1071/NSv20n2

110. Könings KD, de Jong N, Lohrmann C, et al. Is blended learning and problem-based learning course design suited to develop future public health leaders? An explorative European study. *Public Health Reviews*. 2018;39(1):13. doi:10.1186/s40985-018-0090-y

APPENDIX

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Pg 1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Pg 8
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Pg 24
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Pg 23
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Pg 23
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Pg 25
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Pg 25
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Pg 26
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to	

		identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	
	23b	Discuss any limitations of the evidence included in the review.	
	23c	Discuss any limitations of the review processes used.	
	23d	Discuss implications of the results for practice, policy, and future research.	
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	

Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	