Summer 8-7-2020

Emerging Infections: The World is not safe until Countries invest in Public Health Infrastructure. A Closer Look at Sub Saharan Africa (SSA) Public Health Infrastructure during COVID-19 Pandemic.

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Capstone Paper

July 12, 2020

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Abstract

COVID-19 pandemic threatens public health systems across the globe. The ravaging COVID-19 virus does not spare public health systems of large economies such as the US. There are global shortages of PPE, laboratory, and critical care capacity is overwhelmed by the pandemic. Well-resourced public health care infrastructure is essential in reducing mortality, and disease burden in an epidemic, promoting global health security and safeguarding the progress made in other health programs such as HIV/AIDS and TB.

When public health care systems in high-income countries are struggling to manage COVID-19, the situation is worse for under-funded public health systems in SSA. Endemic disease burden and brain drain are straining the deprioritized public health care systems. The 2014-2016 Ebola virus tested Africa's healthcare infrastructure's preparedness. There was no physical infrastructure, and public health systems were ill-equipped before the Ebola outbreak in Guinea, Liberia, and Sierra Leone.

Three years later, public healthcare infrastructural gaps still exist in SSA during the COVID-19 pandemic. Laboratory and critical care capacity, readily available medical supplies, and healthcare personnel are crucial in fighting a highly transmissible viral disease such as COVID-19. SSA still suffers from inadequate public health infrastructure, which slows down efforts to manage the COVID-19 pandemic. Reliable and sustainable funding towards health enables long term planning, thereby allowing healthcare systems to improve and deliver better and timely responses to public health threats. Creating domestic capacity for medical supplies offers readily available supplies while setting up pandemic funds provides immediate financial support during a pandemic.

Keywords: Health system, healthcare infrastructure, public health infrastructure, global health security, emerging infections, endemic diseases, public health threats, sustainable funding.

Introduction

The Role of Public and Health Care Infrastructure

Health care infrastructure is essential and requires adequate resources to function. In resource-limited countries such as SSA, public health infrastructure can become deprioritized compared to other essential needs. A health system encompasses the full continuum between public health (population-based services) and medical care (delivered to individual patients) (Woolfe, 2013).

Most countries in SSA have two health systems that run in parallel. There is a public health system that is solely funded by the government, and the services are either free or subsidized. On the other hand, there is a private health system, a for-profit health system run by private providers. This paper will discuss the public health and healthcare infrastructure for SSA, the infrastructure within the public health system.

The US public health services are a component of the health system. However, the services are fragmented and funded by the federal government, different agencies and private organizations, and most of the funds are earmarked for specific disease priorities (Woolfe, 2013)

Public health and healthcare infrastructure will be used in this paper to describe the built environment and supporting elements such as information technology, equipment access, processes, and staff (Luxon, 2014). A robust healthcare infrastructure provides equitable health and is associated with good health outcomes throughout the life course and health emergencies. A functional healthcare infrastructure facilitates proper planning of primary, secondary, and tertiary levels of care, making public health emergencies more manageable (Ntuli et al.,2018). At the primary level, the public health infrastructure is essential in disease prevention through

surveillance and monitoring. Secondary level infrastructure is vital in diagnostic and curative services through laboratories, staff, medical equipment, and supplies. At the same time, the tertiary level is the advanced level of care (Ntuli et al., 2018). Without adequate functional public healthcare infrastructure, disease transmission, and mortality rates increase. A weak public health infrastructure incapable of meeting basic healthcare needs cannot manage a rapidly evolving global pandemic such as COVID-19.

Globalization brought about free movement of goods, services, and people across porous borders. As a result, one country's failure to manage a public health threat increases the chances of a spillover effect across the globe. The emerging infections that are crossing borders call for strengthening public and healthcare infrastructure at national levels. This paper will examine the challenges with public health infrastructure during COVID-19, particularly in SSA, using available literature and the author's experience working in one of the SSA's healthcare systems. The paper will offer policy recommendations that help SSA better prepare for any public health threats and reduce mortality and risk of spillover within the SSA region or global.

Lessons from previous viral infections

SARS, H1N1, and H7N9 Viruses. The 2002 to 2003 Severe Acute Respiratory Syndrome (SARS) virus caused silent, deadly pneumonia in China and killed 8000 people globally (Bouey,2020). During the SARS outbreak, China had no center for disease control that would have maintained a surveillance system to track emerging infections, and it lacked a national case reporting system (Bouey, 2020). All these gaps contributed to the global health threat posed by SARS and China's lack of public health risk communication (Frost et al., 2019).

After learning from SARS experience, China invested $850 million in its public health care infrastructure to set up a three-tiered network for disease control and prevention systems (Bouey,

2020). In 2004, the United States Center for Disease Control (CDC) collaborated with the Chinese National Influenza Center (CNIC) to build capacity in influenza surveillance (Bouey, 2020). The 2009 H1N1 virus that originated in Mexico found China better prepared than during the SARS outbreak. China became the first country to mass-produce the H1N1 vaccine globally (Bouey, 2020). The improvement in China's public health infrastructure helped control and prevent the 2013 H7N9 virus outbreak that originated in China (Linong, 2013). The H7N9 virus outbreak did not cross borders beyond mainland China due to the public health infrastructure that China put in place. Further, China invested more in the CNIC between 2010 and 2014 by increasing laboratory services, sentinel hospitals, and trained public healthcare professionals. In the three years, China built 408 laboratories, 554 sentinel hospitals, and trained 2500 public health staff (Song et al., 2019).

Ebola Outbreak. The 2014 to 2016 Ebola outbreak in West Africa exposed some weaknesses in their public healthcare system. Before the epidemic spread to neighboring countries, it started in Guinea and went for several months without being detected due to non-existent disease surveillance and reporting systems (WHO, 2015). Previous civil wars damaged the public healthcare infrastructure in Guinea, Liberia, and Sierra Leone, and these countries were ill-equipped to manage the Ebola epidemic. Before the outbreak, healthcare worker capacity was one to two per 100 000 people (WHO, 2015).

Lack of diagnostic facilities such as laboratories delayed accurate diagnosis. More than 800 healthcare workers contracted the disease, and more than 500 died because of insufficient protective equipment and not understanding the virus (Moon et al., 2015). Also, poor transport and telecommunication networks delayed patients' transportation, laboratory samples, and health education outreaches (WHO, 2015). The healthcare infrastructural inadequacy during the Ebola

outbreak caused the human loss of about 11,310 deaths and threatened global health (WHO, 2016).

Background

An Overview of SSA

While pandemics require global solidarity, the SSA governments should take the lead in addressing public health and healthcare infrastructure in their countries as a matter of urgency. SSÁ is a region in Africa that comprises 46 countries south of the Sahara Desert, and it excludes eight Arab countries in North Africa. The paradox of SSA is that despite vast mineral resources such as diamonds, gold, platinum, tourism, and home to the world's 9th exporter of oil, there are significant levels of poverty and disease within its population. The standard poverty rate in SSA is 41%, and of the 28 world's poorest countries, 27 are in SSA (Jollife et al.,2018). As mentioned before, there is a substantial communicable disease burden in this region of Africa.

Corruption is endemic in SSA. There is the diversion of public money by the elites, leaving the population impoverished (United Nations Economic Commission for Africa, 2016). Transparency International (TI) always ranks SSA the highest in the world when it comes to corruption (TI, 2016). More so, there is political instability, recurring civil wars, and terrorist insurgency in some countries in SSA. SSA depends on global funding and loans, and in 2017, the World Bank Group pledged 57 Billion to SSA for the fiscal year 2018-2020 (WB, 2017). SSA countries were to use the funds for transformative projects and support after a crisis (WB,2015). There is also a massive presence of donor agencies in the form of NGOs who are running various public health programs, USAID, UNICEF, World Food Program, The Bill Gates and Clinton Foundations, among others. The NGOs are funding and running HIV, TB, and malaria programs.

Map:

North Africa

Sub-Sahara Africa

Public Health Infrastructure in SSA

Despite the global funding and donor presence in SSA, the healthcare infrastructure fails to meet the basic health needs, let alone a global pandemic. The recurrent cholera outbreaks, a diarrheal disease that requires primary treatment of hydration, good hygiene, and sanitation, are evidence of failing public health infrastructure in SSA (Mengel et al. 2014). According to the United Nations report, only one-third of the SSA population has access to proper handwashing, and 58% have access to clean water. The lack of clean water in SSA is a challenge during COVID-19 that requires frequent handwashing.

Shortages of Health Personnel. The region is also greatly affected by the massive migration of health professionals, and academics from SSA for high-income countries. A study done by Canadian scientists noted that it costs South Africa $59,000 to train a doctor only to migrate to more prosperous countries (Labonte et al., 2007). The loss of trained health personnel costs SSA 2 Billion annually (Misau, 2010). The migration left SSA with under-staffed health facilities and a ratio of less than one doctor per 10 000 people, compared to 24 and 27 per 10 000 people in the US and UK, respectively (Kollar &Buyx, 2013).

WHO estimates that a healthcare system with less than 23 health workers per 10 000 people cannot deliver the care needed for a population (Allutis, 2014). SSA carries 24% of the global disease burden and has only 3% of the world health workers, while the US has 10% of the global burden of disease and 37% of the world health professions (Castillo-Laborde, 2011). The average nurse per population ratio is 1.1 nurses per 10 000 people, while the US and UK have 98 and 101, respectively (Kollar&Buyx,2013). Health care staff shortages perpetuated by the

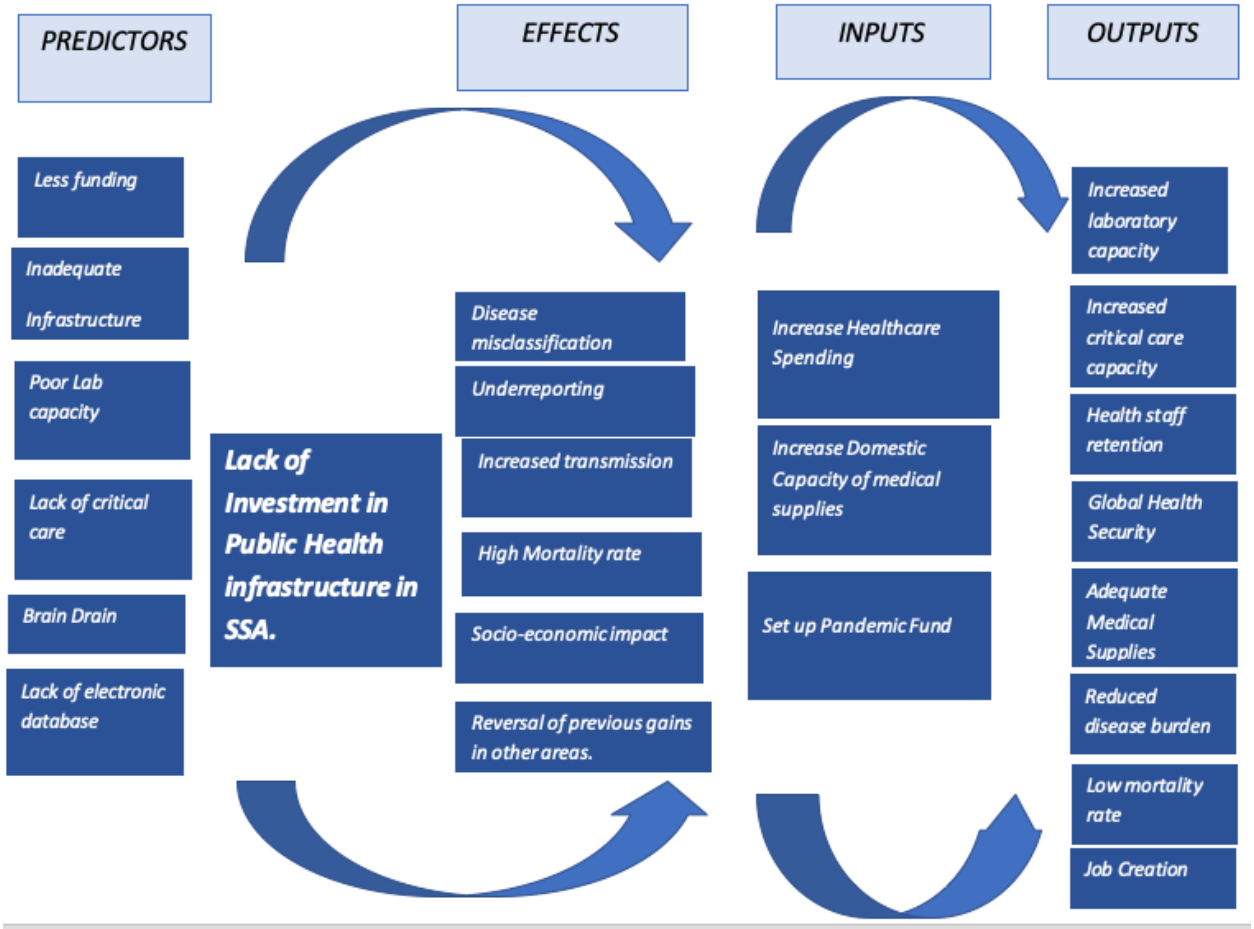
migration of skilled workers to high-income countries have both human and economic impacts. During the COVID-19 pandemic, Africa CDC is voicing concerns that when testing kits are available, there are no skilled workers to do the testing (Africa CDC, 2020). The above statistics are troubling, given the disease burden in SSA and the caseload during the COVID-19 pandemic that requires enough health workers.

Laboratory and Disease Surveillance. Lack of disease surveillance in SSA leads to underreporting, while lack of laboratory infrastructure leads to delays in case identification and disease misclassification. For example, in Guinea's Ebola outbreak, the epidemic went undetected for several months due to a lack of disease surveillance systems. Laboratories are essential in public health in the detection, control, and prevention of diseases. There are also chronic shortages of reagents, and laboratory scientists, power outages, obsolete equipment, and a limited test menu (UNICEF, 2016). Early April 2020, there was no approved rapid diagnostic testing for COVID-19 across Africa (Adebis et al.,2020). As of June 18, Africa, with a population of 1.3 billion, had recorded 276,733 COVID-19 cases, and 7,417 deaths (CDC, 2020). The low numbers of COVID-19 cases are tied to a lack of testing capacity and underreporting in SSA. The limited number of laboratories is impeding efforts to ramp up testing. For example, of the laboratories that test for COVID-19, by May 2020, Ghana had 5, Malawi 3, Zimbabwe one, and Nigeria, with a population of 200 Million had 25 (WHO, 2020).

PPE and Medical Supplies. Global pandemics affect the supply chain and goods movement due to customs and trade laws and shipping logistics. According to WHO, the world will require approximately 89 million face masks every month to fight COVID-19. PPE's need places most countries in SSA at a disadvantage since it depends on foreign aid and imports. SSA imports more than 90% of its medical supplies (WB. 2019). The shortages of medical supplies and PPE

have created competition on the market, which is a disadvantage to SSA as donor countries battle to stock supplies in their home countries. As such, frontline workers in SSA are exposed to COVID-19 due to a lack of PPE. Public hospitals in Zimbabwe closed operations as workers protested shortages of PPE (UN Report, 2020). According to the Nigeria Center for Disease Control (NCDC), lack of compatible equipment hindered scaling up COVID-19 testing. Laboratory infrastructure and PPE are crucial in highly infectious diseases such as COVID-19 for the protection and prevention of disease transmission.

Logic Model



Initiatives to improve Public Health Infrastructure in SSA

According to The Revised Migration Policy Framework for Africa Plan of Action (MPFAPA) adopted in 2018 by the African Union, labor migration is part of the nine thematic areas in this document (African Union., 2018). They recommended strategies of retaining human resources by offering gainful employment, educational opportunities, and professional development. Budgetary constraints limit the SSA government to maintain health care staff and curb global migration; as such, the MPFAPA remains on paper and with no results to show. Meanwhile, IOM launched a Migration for Development in Africa (MIDA) program that mobilizes the diaspora's skills and financial resources to support development in their home countries (IOM). The program helps in capacity building and assists African governments in benefiting from the investments they put into their nationals (IOM).

SSA's interest in investing in laboratory infrastructure saw the launch of Strengthening Laboratory Management Towards Accreditation (SLMTA), a laboratory management training tool in limited-resource settings (WHO, 2009). A World Health Organization (WHO) initiative to strengthen the laboratory systems framework, WHO-AFRO Stepwise Laboratory Quality Improvement Process Towards Accreditation (SLIPTA), followed SLMTA in 2011. There are 340 accredited government laboratories in Africa, and only 28 are in SSA (Schroeder, 2014). The two initiatives are supposed to ensure quality management systems and efficient laboratory services. Despite the two efforts, a study done in 2013 found that 37 countries in SSA had no clinical laboratory accredited to internationally recognized quality standards (Lee et al.,2014). The laboratory staff level ranges from 0.01 to 1.3 per 1000 people in SSA compared to 2.15 per 1000 people in the US (Lee et al., 2014).

Critical care capacity is low in SSA; most countries have a low inventory of ICU beds, with countries such as Malawi with a total of 17 beds countrywide (WHO Report, 2016). During a ministerial forum of China-Africa health development in 2015, China pledged to build 100 hospitals and clinics in Africa, and this is another example of donor dependence by African governments.

Global Pandemic Threats and Interconnections

Global pandemics require collaborative efforts to manage them and reduce disease burden, mortality, economic impact, and prevent the reversal of gains achieved in other areas of public health. The world can not underestimate the severity and pace at which viral infections spread, and every country's infrastructure must have the capacity to handle a pandemic. The 1918 Spanish Flu infected close to 500 million people with a fatality of about 50 million people (Rosner, 2020). Since it started spreading from Wuhan, China, COVID-19 has claimed more than 500 000 people, as of early July, the numbers keep growing globally (WHO, 2020).

Economic Impact. The threat caused by global pandemics has a substantial economic impact. The US most recent federal legislation has availed funds to cushion businesses and job losses. According to the labor department, 20.6 million jobs were lost during the COVID-19 pandemic in the US, increasing the unemployment rate to 14.7% from 3.5% (Labor department, 2020). The economies in most countries in SSA, which are driven by the informal sector and have no social security nets, are severely affected by lockdowns during COVID-19. Informal employment accounts for 89.2% of all jobs in SSA (International Labor Organization (ILO, 2018). The lockdowns have a significant impact as people fail to earn an income due to the closure of places of their informal trade, such as fish and vegetable markets. The World Bank forecasts a loss between 37 to 79 Billion in output loss (WB, 2020).

Risk of Reversal of Public Health Successes. Global pandemics can potentially reverse global gains in areas such as nutrition, HIV, and TB. Already, WHO projects that if there are interruptions of health care programs during COVID-19, a loss of six months' supply of antiretroviral drugs could cost 500 000 lives from AIDS-related illnesses in SSA (WHO, 2020). SSA has 25.7 million people living with HIV, disruptions in supply chains and access to antiretroviral drugs due to lockdowns may reverse the previous gains in HIV control. For example, since the introduction of antiretroviral (ARV) drugs, access and HIV testing services have increased.

As COVID-19 continues to disrupt school-based nutrition programs, the welfare of 368 million children who depend on daily school meals is at stake globally, with SSA accounting for more than 50% of children at risk of losing school meals (UN report, 2020). As a result of the virulence and spread of viral infections, the economic impact, and the threat to past public health successes, public health care infrastructure has to be ready to manage any public health threat and reduce the economic impact and mortality rate.

COVID-19 Response by two different public healthcare systems by June 2020.

While the US and many European countries struggled to cope with COVID-19, Germany's healthcare infrastructure generally coped well during the pandemic. Pre- COVID-19 Germany had an ICU capacity of 29.2 per 100 000 people, compared to 11.5 per 100 000, 3.4 per 100 000 for Italy and Portugal, respectively (Rhodes et al., 2020). The critical care capacity helped Germany reduce the ICU burden of other European countries such as Italy by airlifting COVID-19 patients to its vast critical care infrastructure (McCarthy, 2020). Germany benefited from its innovation-friendly health care system during COVID-19, and its robust healthcare system

contained COVID-19 through extensive testing (Spahn, 2020). Also, Germany leveraged on existing apps and telemedicine to support health workers (Olesch, 2020).

Germany proactively passed the Digital Supply Act law in November 2019, which expanded the digitalization of Germany's health system and enabled doctors to do online consultations and e-prescriptions. The promotion of digital technology use in health systems allowed Germany to meet some healthcare needs within COVID-19 quarantine guidelines. In May, Germany started relaxing social distancing guidelines. As one scientist said, "Germany did not prevent COVID-19 outbreak, but the prevention protocols facilitated the response to the outbreak," Wieler (Robert Koch Institute). The protocols included establishing testing capacities, ample human resources, and physical infrastructure. The existing public health infrastructure in Germany contributed to the success of Germany in containing COVID-19.

In contrast to Germany's public health system response to the Covid-19 pandemic, some public health systems such as New York City (NYC) struggled to contain the virus. COVID-19, a highly transmissible virus, exposed some weaknesses in the US public healthcare system. For example, NYC, the initial epicenter of COVID-19 in the US until May 2020, had a high influx of COVID-19 patients, which threatened its low critical care capacity. NYC had a capacity of 300 ICU beds, and by May 22, it admitted 50 000 patients, and 1000 patients required critical care (Uppal et al., 2020). An NYC study found out that the disease progression of COVID-19 was associated with extra-pulmonary organ dysfunction, high in-hospital mortality, and required mechanical ventilation (Cummings et al., 2020).

NYC's move to expand critical care capacity by creatively transforming non-traditional hospital space into critical care units helped give much-needed critical care to COVID-19 patients (Uppal et al., 2020). However, the shortages of PPE threatened the healthcare workforce,

the frontline workers in the fight against COVID-19. Lack of testing kits delayed case identification and hampered efforts to contain the disease, yet these are the necessary infrastructural requirements in a pandemic. The delay in improving testing capacity may be another contributory factor why the transmission rate in the US remains high. The failure by the US to contain COVID-19 shows the need to invest more in public health infrastructure.

COVID-19 Situation in Donor-Dependent SSA by June 2020. SSA is a unique case when it comes to its preparedness to manage a pandemic such as COVID-19. The 2014-2016 Ebola outbreak in West Africa gave the world a snapshot of the weak public health and healthcare infrastructure in Africa. The high disease burden from endemic diseases in SSA is straining the already weak public health infrastructure. Since cholera resurged in 1970, there have been recurrent outbreaks in SSA (Mengel et al., 2014). In 2011, SSA accounted for 86% of reported cholera cases and 99% of deaths worldwide (Mengel et al., 2014). Between 2015 and 2018, there were subsequent cholera outbreaks in several countries in SSA that include Zambia, Zimbabwe, Kenya, Malawi, Mozambique, and DRC (Mukeredzi, 2019).

On the other hand, HIV makes people immune-compromised and predisposes them to viral infections. SSA has more than two-thirds of the world's population living with HIV, with approximately 1 in every 25 adults living with HIV (WHO, 2018). Besides, SSA constitutes 11% of the world's population, yet it accounts for 49% of maternal deaths (Touray, 2016). Further, SSA has the highest global malaria burden; in 2018, it had 93% cases and 94% deaths (WHO, 2019). Hence, given the above background, and weak public and healthcare systems, SSA may find it challenging to manage a pandemic such as COVID-19.

As COVID-19 spreads across the globe, early March, only South Africa, and Senegal in SSA could test the virus (WHO, 2020). Some countries in SSA were competing with big

economies to procure testing kits, while others were waiting for donations (CDC Africa, 2020). Most countries in SSA have low laboratory and critical care capacities, obsolete or non-functional equipment, shortage of supplies, and staff. Current records indicate that Malawi has 16 million people, yet there are 25 ICU beds and 17 ventilators (Touray, 2016). The situation of low inventory on ICU beds affects the majority of countries in SSA. Critical care capacity is crucial in reducing mortality, especially in viral conditions that cause respiratory dysfunction.

Country	Healthcare Expenditure as % of GDP	COVID-19 Testing rate/Million people	Critical Care capacity. Public ICU beds/population	COVID-19 Cases (as of 7/12/20	Covid-19 Deaths (as of 7/12/20)
Uganda	6.19	0.005	55/ 44 M	1,025	0
Botswana	6.13	0.017	150/ 2.4 M	399	1
Somalia	3.5	0.00005	15/ 15 M	3,059	93
Malawi	9.65	0.00023	25/ 17 M	2,364	38
Nigeria	3.78	0.00095	120/ 198 M	32,558	740
Namibia	8.55	0.005	18/ 2.5 M	861	1
South Africa	8.11	0.038	2,238/ 58 M	278,242	4,079
Rwanda	7.8	0.015	39/ 12.3 M	1,337	4

Table 1. *Comparison of Healthcare allocation as a percentage of the GDP with critical care capacity, laboratory testing capacity, COVID-19 cases, and deaths.*

Global Support for SSA COVID-19 Response

WHO upgraded COVID-19 from a global threat to a pandemic on March 11, 2020, and there was global solidarity to contain the virus and mitigate the transmission. During the same month, the World Bank responded with almost a billion dollars to Africa for strengthening its COVID-19 response and healthcare systems (WB, 2020). Through USAID, the US donated 1000 ventilators and accompanying equipment worth 14 Million to South Africa and 270 million across SSA to help in outreach, messaging, and strengthening laboratory capacity and surveillance (USAID Report, 2020). Philanthropist Jack Ma, the founder of Alibaba, donated medical supplies and PPE to all 54 countries in SSA (CGTN Africa, June 23, 2020). Immediately, governments in SSA responded by instituting lockdowns, airport screenings and closed their borders to non-essential services. At the same time, WHO's Africa regional office and Africa CDC, with the US CDC's guidance, provided technical support to African countries.

Recommendations

The initiatives taken by SSA governments to address the gaps in public health infrastructure is showing little progress as COVID-19 sweeps through SSA. Low testing capacity is leading to underreporting. Given the health and economic impact of global pandemics such as COVID-19, SSA needs to strengthen its public health infrastructure to respond to health emergencies better by increasing healthcare expenditure. Health care infrastructure varies per country in SSA, but the common denominator is that it is under-funded. In 2001 at the Abuja conference in Nigeria, African governments pledged to increase budget allocation towards health to 15% of the GDP. Nineteen years later, the average budget allocation towards health in SSA is 6.6%, far below the 15% agreed at the Abuja conference (WB, 2017). The US allocates 17.8 % of GDP towards health, and Switzerland spends 12.4% (Papanicolas et al., 2018).

Recommendation 1. Governments in SSA must take full ownership of funding their public healthcare systems and safeguard their citizens' health and prevent disease spread across the globe. Unfortunately, there has been a substitution effect in developing nations where governments reduce domestic healthcare spending in response to increased donor funding (Gostin, 2014). The SSA governments reduce budget allocation to health care because of donor dependence. Donor funds are not for national health use; they target troubled areas such as HIV, TB, and Malaria. The Global Fund invests about 4 Billion per year to support programs such as HIV, TB, Malaria in 100 countries that include SSA (Gostin, 2014).

When the health care system receives enough budget, the money can build much-needed infrastructure in areas such as water and sanitation, remuneration of healthcare staff, equip hospitals, and increase capacity in critical care and laboratory services. Ultimately, this would reduce the endemic disease burden and donor dependence, leaving SSA in a better position to tackle emerging infections such as COVID-19 and being self-sufficient. A cross-sectional study in Europe to examine the effects of government healthcare spending on population mortality rates found that a 1% decrease in healthcare spending was associated with a significant increase in all mortality metrics (Budhdeo et al., 2015).

A study carried out to analyze the relationship of health expenditure and health outcomes in BRICS countries that comprise Brazil, Russia, South Africa, India, and China found that public health expenditure plays a role in providing better health care to people in BRICS countries (Jaya, 2016). The impact on reduced budget allocations towards health and neglecting public health infrastructure has immediate adverse economic and health outcomes to countries. It increases the global risk for a public health disaster. The limitation with increasing health care expenditure as a percentage of the GDP is that countries in SSA without diversified economies

have low economic performance, and a low GDP may not be able to increase budget allocation towards health.

Recommendation 2. PPE has been in short supply since the COVID-19 pandemic, and governments must encourage and support healthcare supplies' domestic capacity through tax breaks and encouragement of innovative entrepreneurship. For example, China has a robust young generation of intrapreneurs who participate in the production of goods and services. As a result, Chinese-made products are everywhere globally, and China is a global supplier of medical supplies. While the US has the Defense Production Act, which encompasses a broad civil and military mobilization effort to produce PPE and medical supplies during war and pandemic time, African governments should promote innovative entrepreneurship and offer incentives to those venturing into medical supply businesses. The creation of a domestic medical supply base can feed domestic consumption while exporting surplus units. Private companies may not have the motivation to produce PPE and medical supplies with periodic demand unless the government provides incentives. Government incentives in the form of tax breaks can lure intrapreneurs into such businesses. However, not every country in SSA has a comparative advantage in the production of emergency medical supplies. Countries with technology to do so can supply domestic consumption and export excess within the region. The existence of a regional medical supply chain of medical supplies facilitates timely response to a pandemic such as COVID-19, which in turn prevents disease transmission and reduces mortality rate.

Recommendation 3. Governments in SSA can create a pandemic fund for interested countries to draw from during need, and the African Development Bank (ADB) can manage it. The ADB was established in 1964 and serves 54 African states and 26 non-African countries. Currently, the ADB boasts fifty-five billion in loans and grants earmarked for member countries'

economic development, equity investments, and technical assistance (Investopedia). In July 2020, ADB provided a $5 billion loan to South Africa to fight COVID-19 (ADB, 2020). The history of ADB gives it a better position to oversee the pandemic fund since the misappropriation of funds by governments in SSA accounts for a 25% loss of development resources (TI, 2017).

The European Union (EU) has a similar fund called the European Union Solidarity Fund (EUSF); it provides financial support to member states in the event of a major disaster (European Union, 2020). Since the EU set up the EUSF in 2002, it has financially assisted in eighty disasters in Europe totaling more than 5 billion euros that include earthquakes, forest fires, floods, storms, and drought (European Union, 2020). The limitation on EUSF is that it funds different types of disasters, which can potentially deplete the funds, leaving little funds for a significant public health threat, such as COVID-19. Instead, a pandemic fund earmarked for a specific purpose, gives the portfolio room to grow.

Other stakeholders to contribute towards the pandemic would be businesses, charity organizations, and pharmaceutical companies. Pandemic funds would give SSA governments a step ahead during a global pandemic rather than wait for donor funds to trickle.

Implications

Increasing Healthcare Spending. When healthcare funding increases, it can be used to increase salaries to curb brain drain, reduce disease burden and mortality, equipping the hospitals, and improving the healthcare worker per population ratios. Overall, the budget increase may improve health indicators and help SSA achieve the 2015 Sustainable Development Goals and direct priorities towards emerging public health threats.

The reason for the loss of health workers is due to poor salaries and working in poorly resourced settings. Staff shortages and the continually evolving nurture of COVID-19 make it

even harder for poorly resourced SSA nations to manage the pandemic. For example, in Zimbabwe, where health care workers protest for PPE and poor salaries, there are disruptions in other essential services such as childbirth.

The limitations of increasing expenditure are that the political instability in SSA often leads states to shift priorities. Emerging priorities in counterterrorism and civil wars may cause healthcare spending to receive less priority. For example, Kenya, Somalia, and Ethiopia are fighting Al-Shabab terrorists, while Nigeria is fighting Boko Haram terrorists. Additionally, there is a protracted civil war in DRC, which is threatening the available healthcare infrastructure. Twice in 2017, Doctors Without Borders' makeshift Ebola clinics were burned (MSF, 2017).

Despite the instability in parts of SSA, the region has a diversity of economies that boast of vast mineral resources, eco-tourism, and agriculture. These resources generate substantial revenue, which can fund public health infrastructure development.

Creating Domestic Capacity for Medical Supplies. On the other hand, establishing and supporting medical supplies' domestic capacity will help SSA have the needed supplies to prevent disease transmission during pandemics. Also, establishing the medical supplies industry increases technology transfer within the region. The 2014 to 2016 Ebola outbreak cost lives of more than 240 healthcare workers due to shortages of PPE (WHO, 2014) and the improper wearing of PPE due to exhaustion. PPE is essential in the prevention of disease transmission within the healthcare personnel and the community at large. When the population has access to the resources, they are likely to comply with the stipulated preventive guidelines. When there is domestic capacity through private companies, the government's role will be to regulate the medical supplies and implement quality control measures.

Global demand creates competition for PPE and medical supplies; this leads to the proliferation of unregulated suppliers. There is a risk of counterfeit products when the market is unregulated, which negates the fight against COVID-19 as more people are exposed to the virus. On April 1, 2020, CNN covered a story where a medical center in the US received a batch of counterfeit N95 masks from a supplier. If the Medical Center had not caught the fraudulent consignment, dozens of its healthcare staff and patients would have been exposed to COVID-19. Governments in SSA can save significant amounts of money when they manufacture their own PPE and medical supplies and can avoid being dumping grounds for counterfeit consignments. Imports are costly and time-consuming due to buying and shipping costs and port charges.

Private clothing manufacturing companies in some countries in SSA, for example, Kenya, took advantage of the gap in PPE supply and switched to massive production of PPE. While production of PPE by clothing companies fills the gap and mitigates transmission of COVID-19, there is also a slowdown in their production lines. Instead, when there is an establishment of medical supplies companies, they will not be disruptions in other economic areas. Setting up a domestic base for medical supplies would also bring jobs to SSA, where unemployment rates are high. For example, South Africa, the biggest economy in Africa, has an unemployment rate of 47.3% (Abraham et al.,2019).

Creation of a Pandemic Fund. Instead of depending on donor funds, the pandemic fund will break donor dependence by creating a local emergency fund readily available to fight pandemics such as COVID-19. Case in point, WHO projects 3.6 to 5.5 million COVID-19 hospitalizations, and between 52 253 to 106 559 will require critical care in SSA (BMJ, 2020). SSA is failing to procure enough COVID-19 testing kits and is dependent on donations, slowing down testing (Nigeria CDC, 2020). By the end of May, SSA had tested only 1.3 Million people, one test per

1000 people (Kengasong, 2020), compared to 30 tests per 1000 people in the US (CDC, 2020). The slow progress in testing delays efforts on mitigating the spread of COVID-19. The fund would help reduce the mortality rate by funding the procurement of medical supplies, oxygen, and more staff hiring to boost capacity.

Conclusion

The existence of infrastructural gaps in SSA is a cause for concern for the citizens and the global community in the wake of recurring and emerging infections. Globalization has increased the mobility of highly transmissible viruses. Disease surveillance, monitoring, and case identification through reliable laboratory infrastructure are crucial in public health; and supported by critical care, availability of human resources, equipment, and medical supplies. This essential public health infrastructure is inadequate in SSA, and it threatens global health. High disease burden caused by endemic infections strains the already weak health care infrastructure. Instead, SSA needs to abide by the Abuja declaration, which advocates for an increase in healthcare spending. Also, SSA states need to build domestic capacity for medical supplies and create emergency funding to tap into during pandemics. These initiatives would reduce donor dependence, boost domestic capacity, promote public health and healthcare infrastructure development, and enable quicker response to public health threats. Ultimately, this will mitigate disease transmission, reduce mortality, and maintain global health security.

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Appendix A: USF Competencies

USF MPH Competencies	Description of how used for Capstone
1. Compare the organization, structure and function of healthcare, public health and regulatory systems across national and international settings.	I analyzed health systems of Sub Saharan Africa and factors affecting public health infrastructure development. I made recommendations after a comprehensive review of literature.
2. Select quantitative and qualitative data collection methods appropriate for a given public health context	I analyzed data from primary, secondary, and tertiary sources to support the argument that public health infrastructure is essential in the wake of emerging viral infections, and SSA is vulnerable during COVID-19.
3. Develop recommendations to improve organizational strategies and capacity to implement health policy	After reviewing the literature, I identified the existing gaps that slow down the response to Covid-19 in SSA and made policy level recommendations.
4. Communicate audience-appropriate public health content, both in writing and through oral presentation	I outlined, drafted and finalized Capstone paper including a literature review, recommendations and implications of investing in public health infrastructure. I created a slide deck based on the Capstone paper and delivered oral presentation at Health Professions Day in front of an interprofessional audience.