Understanding Individual and Social Risk Factors Related to Priority Zoonotic Diseases in West Africa

A Review of the Literature

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List of Acronyms

CCP	Center for Communication Programs
CHV	Community Health Volunteers
EVD	Ebola Virus Disease
HPAI	Highly Pathogenic Avian Influenza
JEE	Joint External Evaluations
LBM	Live Bird Markets
LFV	Lassa Fever Virus
MARV	Marburg Virus
NGO	Non-governmental Organization
PZD	Priority Zoonotic Diseases
RBPT	Rose Bengal Plate Test
RIG	Rabies Immunoglobulin
SBC	Social and Behavior Change
SLAWS	Sierra Leone Animal Welfare Society
USAID	United States Agency for International Development

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Executive Summary

After the Ebola epidemic in West Africa ended, many countries in West Africa prioritized prevention programs and preparedness strategies for future public health emergencies. To help support these efforts, the World Health Organization led Joint External Evaluations of country capacity to prevent, detect and rapidly respond to public health emergencies; risk communication, community involvement in prevention strategies, and national response efforts were identified as areas for improvement. Supporting the development of functional risk communication systems requires a better understanding of the individual and social behavioral risk factors related to priority zoonotic diseases.

This literature review summarizes the available published literature on behavioral determinants and sociocultural systems and norms that influence specific priority zoonotic diseases in West Africa. It provides a starting point for further qualitative and quantitative investigation to inform the development of social and behavior change resources and tools that may contribute to the development and maintenance of effective risk communication systems. The search was conducted in Embase, and inclusion criteria for the articles were that they: (1) have a focus on any of anthrax, avian influenza, *Brucella*, *Mycobacterium*, plague, rabies, *Salmonella*, and viral hemorrhagic fever; (2) were conducted in West Africa; (3) were published between 2008–2018; and (4) describe individual, cultural, or social risk or prevention factors related to one of the eight zoonotic diseases.

The literature search uncovered a total of 103 articles that met the inclusion criteria, including 19 for avian influenza, 20 for *Brucella*, 7 for *Mycobacterium* (specifically bovine brucellosis), 14 for rabies, 7 for *Salmonella*, and 36 for viral hemorrhagic fever (including Ebola [20], Lassa fever [10], Marburg [1], and arboviruses [5]). Key socio-behavioral and risk determinants from the review follow.

Avian Influenza

Populations identified as most at risk for avian influenza included military personnel, health workers, farmers, abattoir workers, and individuals trading in poultry. Risk factors for avian influenza included proximity of humans to infected birds and poor biosecurity measures. Barriers to prevention included inadequate and unenforced farming regulations, knowledge deficits, costs, and low-risk perception. Recommended interventions were biosecurity measures including hand washing, surveillance, and establishment of reporting systems.

Brucellosis, *Mycobacterium*

Vulnerable populations and risk factors were similar for brucellosis and *Mycobacterium*. At-risk populations included livestock keepers, meat processors and consumers, and dog owners. Infection in humans was acquired through airborne particles, consumption of unpasteurized milk or poorly cooked meat, and contact with fetuses and vaginal or amniotic fluids of infected animals. Infection in animals was primarily through poor vaccination and quarantining practices, sharing bulls for breeding purposes,

and feeding cow fetuses to dogs. Factors hindering effective prevention included lack of knowledge of prevention methods, cultural culinary practices, and costs associated with vaccination. Recommended prevention practices included separating living areas of animals and humans, increasing awareness and knowledge of appropriate milk and meat processing, safe slaughtering, protection from contamination during animal births, appropriate disposal of animal carcasses, vaccinations, and not mixing different herds.

Rabies

Information about sociocultural norms and behaviors related to rabies was surprisingly scant. While the general public has a risk of rabies infection, children, dog owners, health care workers, and traditional healers comprised the groups with increased risk. Risk factors described included dog bites and the processing and consumption of dog meat. Awareness campaigns and mass animal vaccination were recommended for prevention of rabies; however, barriers included cost of vaccination, lack of vaccine supply, and poor knowledge of transmission and strategies for prevention of rabies among the population.

Salmonellosis

Groups with increased risk for salmonellosis included poultry, cattle, and swine farmers; abattoir workers and butchers; and the general public. In animals, infection spreads primarily through poor biosecurity measures and proximity of other carriers, infected animals, and pests. For humans, the risk for salmonellosis was higher on farms that used shared equipment. Recommended practices were biosecurity measures like hand washing, cleaning and disinfection of poultry houses, more hygienic slaughtering practices, and health communication to provide public education.

Hemorrhagic Fevers (Ebola, Lassa, Rift Valley, Yellow Fever)

The majority of information available in the literature was for Ebola virus disease. The general public was considered to be at risk for all the viral hemorrhagic fevers. Groups such as hunters, bushmeat handlers, students, and health care workers were described as more vulnerable to infection with Ebola. The rural poor and those handling rats were most at risk for Lassa fever. Livestock keepers, meat handlers, processors, and consumers were at risk for Rift Valley fever. Consumption of bush meat, handling and butchering infected animals, contact with bats, and contact with infectious persons and corpses were risk factors for Ebola. Traditional burial practices, eating rat meat, or contaminated meat or water increased the risk of Lassa fever. Barriers to risk elimination included entrenched beliefs that bush meat was safe to eat, poor knowledge and myths surrounding the disease, and poor regulation of hunting laws and bans. Dry spells that were followed by a period of intense rain and humans' close proximity to livestock were considered risk factors for Rift Valley fever. No recommendations for behavioral interventions were described for Ebola; however, health communication, animal vaccinations, vector control, and protections when handling meat and corpses were recommended approaches for decreasing risk of hemorrhagic fever.

Overall, excluding Ebola virus disease, avian influenza, and to some extent brucellosis, there were few publications on behavioral and community-level determinants of risk for the majority of priority zoonotic diseases included in this literature review. The majority of factors associated with risk were closely related to a lack of awareness and knowledge of zoonosis, strong cultural beliefs around food and burials, and poor hygiene and biosecurity measures. Common structural barriers that affect risk mitigation and prevention efforts included costs associated with vaccinations, quarantining, and biosecurity measures, as well as a lack of vaccines, and poor regulation of the farming and meat processing industry.

Introduction

After the Ebola virus disease outbreak in West Africa in 2014-2016, West African nations are increasing efforts to prevent and prepare for future public health emergencies. As part of this process, the World Health Organization has led Joint External Evaluations (JEE) of country capacity to prevent, detect, and rapidly respond to public health risks.

One of the parameters the JEE evaluates is risk communication, which includes dissemination of timely information about health risks and events to the public through the appropriate channels in order to promote prevention and control actions at the individual, family, and community levels. In order to improve risk communication systems, governments must develop multi-sectoral communication strategies that provide the link between human health, animal health, and the environment. This approach, called "One Health," explicitly considers the intersections between human health, animal health, and the environment, as well as how actions in one area affect the other two.

Supporting the development of functional risk communication systems requires a better understanding of the individual and social risk factors related to each of the priority zoonotic diseases. The purpose of this literature review is to provide a starting point for further qualitative and quantitative investigation to inform the development of social and behavior change (SBC) resources and tools. These resources and tools will contribute to the creation and maintenance of effective risk communication systems.

Specific objectives for the Breakthrough ACTION Global Health Security Agenda program vary by country and may include to: gain understanding of individual and social determinants of risk of infection and perceptions of risk; build functional systems of community engagement to facilitate individual and household adoption of priority epidemic prevention and management behaviors; increase stakeholders' capacity to improve public awareness using mass media and improved communication tools; develop community monitoring tools that contribute to the prevention and management of diseases with epidemic potential; strengthen public sector systems for oversight and coordination of risk communication and SBC activities at the national, sub-national, and community levels; and improve the measurement, coordination, and quality of SBC.

Methods

This report provides a review of the literature of individual and social risk factors related to eight zoonotic disease groups in West Africa. To be included in the review, articles had to (1) focus on one of the eight zoonotic disease groups including anthrax, avian influenza, *Brucella*, *Mycobacterium*, plague, rabies, *Salmonella*, and viral hemorrhagic fevers; (2) be about cases in West Africa; (3) be published in the last 10 years (2008–2018); and (4) describe individual, cultural, or social risk or prevention factors related to one of the eight zoonotic disease groups. The search was conducted in Embase, a comprehensive database of biomedical literature, between April and July 2018.

Results

The literature search uncovered a total of 103 articles that met the inclusion criteria, including 19 for avian influenza, 20 for *Brucella,* 7 for *Mycobacterium* (specifically bovine brucellosis), 14 for rabies, 7 for *Salmonella*, and 36 for viral hemorrhagic fever (including Ebola virus disease [20], Lassa fever [10], Marburg virus disease [1], and arboviruses [5]). These articles are described below, organized by disease group, and presented in alphabetical order. There were no eligible articles returned for anthrax and plague.

Table 1. Summary of results

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Highly Pathogenic Avian Influenza (HPAI)	Peer-reviewed articles (19)	Nigeria (12) Ghana (3) Mali (3) Regional (1)	Military personnel Poultry farmers Abattoir workers Poultry traders	Poor biosecurity measures <u>HUMANS</u> Proximity of humans to infected birds <u>ANIMALS</u> Free-range poultry Unregulated poultry trade Proximity of different bird species Wild bird-domesticated poultry interaction	Strict biosecurity measures Promotion of handwashing may be more acceptable for poorer farmers Effective surveillance and reporting system infrastructure Community leaders could be useful to collect reports Health communication (Education) Advocacy through imams may be more appropriate for Islamic-educated farmers	Inadequate regulation of poultry farming practices Cost of biosecurity equipment Poor knowledge of disease prevention Low-risk perception Poorly designed live bird markets Lack of veterinary services Lack of availability of HPAI vaccine
Brucellosis (cattle, dogs, camels)	Peer-reviewed articles (18) Reports (2)	Côte d'Ivoire (2) Ghana (1) Niger (1) Nigeria (13) Togo (1)	Livestock keepers Meat processors Meat consumers Dog owners Veterinarians	<u>HUMANS</u> Consumption of unpasteurized milk or undercooked meat Contact with aborted animal	<u>HUMANS</u> Raise awareness Boil milk products Cook meat thoroughly Wash hands before and after milking	Lack of knowledge of disease and risk factors Infrastructure of farms and living spaces leads to shared spaces between several

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
		Regional (2)		fetuses or vaginal or amniotic fluids Airborne contaminated particles <u>ANIMALS</u> Not vaccinating Introducing new animals into herds without quarantine, testing, or vaccination Sharing bulls Feeding cow fetuses to dogs	Wear protective clothing when assisting with animal delivery/abortion and wash hands with soap afterwards Separate animals from living spaces <u>ANIMALS</u> Vaccinate Provide mineral supplementation Do not mix herds (with other species or other herds) Test and cull infected animals	types of animals and humans Cultural and culinary practices Lack of economic means to vaccinate
***Mycobacterium* (Bovine Tuberculosis)**	Peer-reviewed articles (7)	Ghana (2) Niger (2) Nigeria (3)	Livestock keepers Meat processors Meat consumers Veterinarians	<u>HUMANS</u> Consumption of unpasteurized milk or undercooked meat Contact with animal carcasses Airborne contaminated particles <u>ANIMALS</u> Introducing new animals into herds without quarantine, testing, or vaccination Sharing bulls Movement of cattle	<u>HUMANS</u> Raise awareness Boil milk products Cook meat thoroughly Wash hands before and after milking Wear protective clothing when slaughtering and processing meat and wash hands with soap afterwards Separate animals from living spaces	Lack of knowledge of disease and risk factors Infrastructure of farms and living spaces leads to shared spaces between several types of animals and humans Cultural and culinary practices Lack of economic means to vaccinate

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
					ANIMALS Vaccinate Provide mineral supplementation Do not mix herds (with other species or other herds) Test and cull infected animals Discard carcasses with lesions (do not sell or consume)	
Rabies (dog, cattle, pig, human)	Peer-reviewed articles (11) Reports (3)	Côte d'Ivoire (1) Ghana (1) Mali (3) Nigeria (6) Sierra Leone (1) Regional (2)	General public Dog owners Children/parents Health care workers Traditional healers Veterinarians	Dog bites Dog meat processing and consumption	Mass canine vaccination campaigns Awareness campaigns	Lack of knowledge of where and when to vaccinate Cost of vaccinating dogs Availability of vaccination points—taking dogs to the veterinarian takes time, is inconvenient (transporting animal), and costly Stray dogs
Salmonellosis	Peer-reviewed articles (7)	Burkina Faso (2) Ghana (1) Nigeria (2) Senegal (2)	Poultry, cattle, and swine farmers Butchers Abattoir workers General public	HUMANS Hygiene control along meat retail chain Consumption of eggs from plastic egg crates Consumption of unfermented soft cheese	Health communication (education) Strict biosecurity measures Prevent cross-contamination; use new utensils after manipulating fresh meat	Lack of refrigerators to store meat at low temperatures at home

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
				ANIMALS Poor biosecurity measures Membership of the farm in a poultry association More than 1-kilometer distance from landfill and other farms Mixed poultry housing system Proximity of other carriers, infected animals, and pests		
Ebola Virus Disease	Peer-reviewed articles (20) (includes 1 multi-country source covering 2 countries)	Sierra Leone (7) Liberia (2) Nigeria (6) Guinea (1) Ghana (4) Benin (1)	General public Hunters Bushmeat handlers Students Health care workers	Handling and butchering infected animals Consumption of bush meat Direct or indirect contact with bats Contact with infectious persons/corpses		Blackmail/threat surrounding hunting laws Belief that there was no threat because hunting/eating wild animals had been done for many years
Lassa Fever	Peer-reviewed articles (10)	Sierra Leone (4) Nigeria (6)	General public, particular rural/poor communities Handlers and eaters of rat meat	Traditional burial practices that expose individuals to blood or contaminated water Handling/ consuming rat meat Eating food that has been dried on the floor (contaminated)	Health communication (education)	Lack of knowledge and misconceptions Lack of education/ awareness in local languages Rat meat is easily accessible

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Yellow Fever (Arbovirus)	Peer-reviewed articles (3)	Côte d'Ivoire (2) Nigeria (1)	General public	Not vaccinated for yellow fever Standing water that creates breeding sites for mosquitoes	Mass vaccination Vector control Bite protection	
Rift Valley Fever (Arbovirus)	Peer-reviewed articles (1)	Mauritania (1)	General public Livestock keepers Meat processors Meat consumers Veterinarians	Environmental: dry spell of 6 days followed by intense rain Proximity to livestock	Vector control Bite protection Boil milk products Cook meat thoroughly Precautions when handling sick animals and carcasses	
Zika (Arbovirus)	Peer-reviewed articles (1)	Nigeria (1)	General public Pregnant women		Vector control Bite protection	

Anthrax

Anthrax is an acute, infectious disease primarily of herbivorous animals. It is a serious zoonotic disease and public health threat because it has the ability to affect a large number of livestock and can be spread great distances to infect other animals and humans (Turnbull, 2008). Anthrax is transmitted to humans from infected animals or animal products by direct contact through a break in the skin (cutaneous anthrax), by eating inadequately cooked meat of an infected animal, or by inhaling the anthrax bacteria or spores (inhalational anthrax). The symptoms of anthrax in humans depend on the mode of transmission and may present as a skin ulcer, flu-like symptoms, chest discomfort, coughing up blood, nausea, abdominal pain, and painful swallowing. In animals, the symptoms of anthrax include high fever, bleeding from natural orifices, and sudden death (Turnbull, 2008).

The search returned 15 articles. None of the articles met the criteria for inclusion in the review and report.

Avian Influenza

Table 2. Summary of results, avian influenza

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Highly Pathogenic Avian Influenza	Peer-reviewed articles (19)	Nigeria (12) Ghana (3) Mali (3) Africa (1)	Military personnel Poultry farmers Abattoir workers Poultry traders	Poor biosecurity measures <u>HUMAN</u> Proximity of humans with infected birds <u>ANIMALS</u> Free-range poultry Unregulated poultry trade Proximity of different bird species Wild bird-poultry interaction	Strict biosecurity measures Promotion of handwashing may be more acceptable for poorer farmers Effective surveillance and reporting system infrastructure Community leaders could be useful to collect reports Health communication (education) Advocacy through Imams may be more appropriate for Islamic-educated farmers	Inadequate regulation of poultry farming practices Cost of biosecurity equipment Poor knowledge of disease prevention Low-risk perception Poorly designed live bird markets Lack of veterinary services Lack of availability of HPAI vaccine

This section reviews the risk behaviors associated with transmission of highly pathogenic avian influenza (HPAI). It also explores the determinants and barriers to uptake of healthy behaviors with HPAI and recommended practices.

Nineteen studies were included in this review on HPAI in West Africa. Two studies focused on HPAI in military personnel, exploring the knowledge of the troops and biosecurity practices with backyard poultry farming on military barracks in Ghana (Agbenohevi et al., 2015; Odoom et al., 2012). One article highlighted the barriers to reporting suspected HPAI cases among Nigerian physicians (Lafond et al., 2014). One study investigated the psychosocial stress, altered livelihood and trauma associated with HPAI outbreaks to poultry farm owners in Nigeria (Fasina, Jonah, Pam, Milaneschi, Gostolli, & Rafanelli, 2010a). Other studies included in the review explored the knowledge, behaviors, perceptions and risk factors related to avian influenza in Nigeria (Adam, Qasim, & Kazeem, 2014; Alhaji & Odetokun, 2011; Elelu, 2017; Fasanmi et al., 2016; Fasina et al., 2016; Fasina, Rivas, Bisschop, Stegeman, & Hernandez, 2011; Fasina, Bisschop, Ibironke, & Meseko, 2009; Fatiregun & Saani, 2008; Musa, Aderibigbe, Salaudeen, Oluwole, & Samuel, 2010; Paul, Assam, & Ndang, 2012), Ghana (Burimuah et al., 2016), Mali

(Molia et al., 2016; Molia et al., 2011; Molia et al., 2015), and across the African continent (Fasanmi, Odetokun, Balogun, & Fasina, 2017).

Highly pathogenic avian influenza is a rapidly disseminating infection that is adapted to birds but can also potentially be transmitted to humans with a stable human-to-human transmission (Fasina et al., 2016; Yang, Halloran, Sugimoto, & Longini Jr, 2007). Migratory waterfowls, most notably wild ducks, are the natural reservoirs of the avian influenza virus (Burimuah et al., 2016). Avian influenza within wild birds maintains its low pathogenicity; however, when transmitted to domestic poultry the virus may mutate to become HPAI (Alhaji & Odetokun, 2011). HPAI is spread from birds to humans through direct contact with infected birds (dead or alive), an infected bird's droppings, or secretions from their eyes or respiratory tract. The first outbreaks of HPAI in Africa were recorded in Egypt and Nigeria in 2006 (Odoom et al., 2012). During the 2006 outbreak in Nigeria, HPAI infection resulted in the death of approximately 711,000 birds of various species, and one confirmed human fatality in Lagos State (Fasina et al., 2011). The symptoms of HPAI infection in humans range from asymptomatic infection, mild upper respiratory disease or conjunctivitis to severe pneumonia with acute respiratory distress syndrome, multi-organ failure and death (Chan, 2002). In birds, HPAI is characterized by sudden onset of severe disease that invades multiple organs resulting in massive internal bleeding and death within 48 hours (Elelu, 2017). Vaccines have been developed for H5N1 HPAI in humans, but they are not routinely available. However, H5N1 HPAI is continuously mutating and, should there be a pandemic, it is likely that development of a vaccine specific to the pandemic strain will take several months. Vaccines against several HPAI strains are available for poultry but the most important protection against HPAI among farm birds is the practice of biosecurity measures (Alhaji & Odetokun, 2011). Biosecurity measures may include cleaning, disinfecting, separate overalls, change of outdoor shoes before entering flock houses, and restriction of visitors (Alhaji & Odetokun, 2011).

Risk factors for HPAI in birds

Factors that are associated with the existence and propagation of HPAI in the bird population include the establishment of H5N1 HPAI in domestic poultry, the abundance of free-range domestic birds, the unregulated international trade of day-old chicks, poor quarantine procedures for newly introduced poultry, close contact between different species of poultry, and the mixture of wild birds and domesticated poultry (Alhaji & Odetokun, 2011; Fasanmi et al., 2017; Fasina et al., 2010b; Molia et al., 2015; Odoom et al., 2012).

A study by Fasina et al. (2011) in Nigeria during the HPAI 2006–2007 epidemic identified statistically significant associations among three risk factors for HPAI on sampled poultry farms: (1) the presence of visitors on farm premises; (2) the purchase of live poultry and poultry products by farmers; and (3) farm workers living outside the farm premises. Receiving visitors on farm premises led to an eight-fold increase in the odds of HPAI infection in poultry on these farms compared to farms where visitors were received outside the premises (OR = 8.32). The authors proposed that the reason for this finding was that visitors often went to several farms in the course of conducting their business and could have inadvertently transmitted HPAI infection from farm to farm. Purchase of live poultry and poultry

products during the outbreak led to an eleven-fold increase in the odds of HPAI infection in the bird population compared to farms that did not make any purchases during the outbreak (OR = 11.91). Having farm workers live outside the premises led to an almost nine-fold increase in the odds of HPAI infection compared to farms that had workers living on site (OR = 8.98). The explanation for this finding as proposed by the authors was that outside workers may have been less likely to observe biosecurity principles and guidelines set by the farms. The authors described findings from another study to support their claims where off-site workers raised poultry in their own homes, offered services to other farms, exchanged items with workers from other farm premises, and rarely changed their clothes and shoes when they reported for work (Fasina et al., 2010).

Factors reported to be associated with HPAI in live bird markets (LBM) in Mali included being open every day, overnight poultry storage, absence of zoning to segregate poultry-related workflow areas, waste removal, cleaning and disinfecting occurring less frequently than on a daily basis, slow disposal of dead birds, and absence of facilities for proper management of bird fecal waste (Molia et al., 2016). The sale of wild birds in northern Nigerian LBMs was also described as a risk factor for HPAI infection (Fasanmi et al., 2016). In an assessment of risk factors for HPAI in LBMs in Nigeria, Fasanmi et al. (2016) reported that mandatory routine disinfection of LBMs, handwashing after slaughter, and traceability of the origin of birds being sold in the LBMs were protective factors against HPAI infection, but hand disinfection after slaughter was a strong risk factor for HPAI infection. The authors pointed out the discrepancies between knowledge and actual practice as possible reasons for this finding. They noted that LBM operators used antiseptics or disinfectants that were minimally applied or over-diluted. In addition, the over-exposure of chemical disinfectant products to direct sunlight might have rendered them ineffective before their use.

The study by Molia et al. (2011) examined the risk factors for avian influenza seropositivity in poultry in Mali. Village backyard birds had significantly higher avian influenza seropositivity (3%) than birds from commercial farms (0%). The research showed that birds from the Mopti area in the Sahelian zone, a common area for wild bird migration, were more seropositive for avian influenza than birds from the Sikasso area of the Sudano-Guinean zone (OR = 2.0). The researchers also found that the odds of avian influenza seropositivity was higher in chickens than in ducks (OR = 5.3).

Risk factors for HPAI in humans

In humans, the risk factors for the transmission of HPAI in West Africa are the proximity of humans to infected birds and poor biosecurity measures in the handling of poultry (Agbenohevi et al., 2015; Elelu, 2017).

Groups of individuals with increased risk of HPAI include poultry farmers, abattoir workers, and poultry traders (N. B. Alhaji & Odetokun, 2011; Elelu, 2017). Military personnel are also a potential at-risk group. Poultry farming in military barracks in Ghana dates back to the “Operation Feed Yourself” program promoted in 1972 that encouraged subsistence farming activities and animal production around the barracks (Agbenohevi et al., 2015). The backyard poultry are characterized by small flocks of birds with low biosecurity measures (Agbenohevi et al., 2015). In Ghana, and also in many other countries in Africa,

military personnel usually live in overcrowded barracks. Together, low biosecurity practices and crowded living conditions favor the animal-to-human transmission of avian influenza. The possibility of an increased risk of HPAI transmission in military personnel is particularly problematic because military personnel are themselves critical players in the response efforts to public health threats such as HPAI outbreaks (Odoom et al., 2012)

Behavioral determinants and practices

Awareness about HPAI

Awareness of HPAI was generally high across the reviewed studies. However, it should be noted that awareness was reported in populations that were exposed to information about HPAI from the mass media and following the HPAI outbreak in Nigeria, or among participants who were quite well educated. Specifically, the majority (97.9%) of the poultry farmers and live poultry sellers in Benin City, Nigeria were aware of HPAI (Adam et al., 2014). However, the authors noted that almost three-quarters (72%) of the sample had at least secondary education (Adam et al., 2014). Similarly, Fatiregun and Saani reported that 92.9% of poultry workers sampled in Oyo State, Nigeria had heard of avian influenza (Fatiregun & Saani, 2008). However, this was post HPAI outbreak and campaigns in Nigeria.

Knowledge about HPAI

Knowledge about HPAI was moderate to low and varied across the various study populations. Level of education influences individual knowledge about HPAI. The study in Oyo State, Nigeria reported that 61.4% of respondents correctly defined avian influenza; however, researchers noted that knowledge was higher among educated poultry farmers (Fatiregun & Saani, 2008). Among poultry farmers in Ikorodu, Nigeria, 41% of poultry farmers with tertiary education and 17.6% of farmers with secondary education had adequate knowledge of HPAI compared to 1.6% with no education and 0% with primary education. Adequate knowledge in this study was defined as a score of more than nine on a 25-item scale (Elelu, 2017).

The length of time spent in the poultry farming profession was also associated with individual knowledge of HPAI. About half (49.6%) of poultry farmers with at least 3 years of experience in the poultry farming business had adequate knowledge of HPAI compared to farmers who had been in business for 2-3 years (4.1%), 1-2 years (3.3%), and less than 1 year (3.3%) (Elelu, 2017). Finally, poultry farmers (57.8%) were significantly more likely to have adequate knowledge about HPAI compared to live bird traders (2.5%) (Elelu, 2017).

Knowledge about transmission of HPAI

Knowledge gaps related to transmission of HPAI were described in several studies. In a survey conducted among poultry farmers from Nigeria, the authors mentioned that only about half of the participants knew that HPAI can be transmitted from birds to humans (50.4%) and 57% knew that HPAI can be transmitted from birds to other birds (Adam et al., 2014). Moreover, only 30% knew that HPAI can be transmitted by contact with infected bird feces, 26.5% knew transmission is possible through handling infected eggs, 17% knew it can be transmitted through vehicular transport of infected birds, and 29.1% knew about transmission through infected slaughter surfaces (Adam et al., 2014). In another

study in a similar population, 72.9% knew that avian influenza can be transmitted from bird to bird, and 55% knew it can be transmitted from bird to human and through handling of uncooked poultry. Only 14% knew about the human-to-human transmission of avian influenza (Fatiregun & Saani, 2008). Knowledge about the mode of transmission of avian influenza was poor among backyard poultry farmers in northern Nigeria. Only a third (33.8%) knew that avian influenza can be transmitted from birds to human (Musa et al., 2010).

Knowledge about preventing HPAI

There was low-to-moderate knowledge of strategies to prevent spread of HPAI between birds and humans. A majority (80.6%) of farmers sampled in Benin City, Nigeria knew that birds could be vaccinated against HPAI, however, only about half (47%) were aware of HPAI vaccination for humans (Adam et al., 2014). In addition, less than a quarter (23.7 %) cited the use of face masks for protection while in the bird pens, 26.7% mentioned disinfection of clothing, and 35.3% mentioned farmworker residence on the poultry farms as preventive measures against the transmission of HPAI (Adam et al., 2014). Only 56.9% of study participants identified hand washing with antiseptic after touching birds as a preventive method against the transmission of HPAI (Adam et al., 2014). In another article, Fatiregun & Saani (2008) showed that two-thirds (65.7%) of respondents knew that wearing a face mask, overalls (67.9%), boots or boot covers (64.3%), and eye protection (57.9%) were measures to help prevent the spread of avian influenza. Other known preventive measures included washing and disinfecting surfaces/body (84.3%), and vaccination of birds (67.9%) (Fatiregun & Saani, 2008).

Behaviors and practices that increase the risk of HPAI

The proper implementation of biosecurity measures for handling poultry is important to prevent the introduction and dissemination of HPAI between birds and from birds to humans. A unifying theme from the literature across the West African countries is the inadequate regulation and low practice of biosecurity on poultry farms (Alhaji & Odetokun, 2011; Fasanmi et al., 2016; Fasina, Rivas, Bisschop, Stegeman, & Hernandez, 2011; Odoom et al., 2012; Paul et al., 2012). Dangerous poultry farming practices such as the killing, eating and selling of sick birds, poor reporting of sick or dead poultry, and disposal of dead birds in public dumps and other areas increase the risk of transmission of HPAI from birds to humans (Molia et al., 2015). Furthermore, poor vaccination coverage and handwashing practices after handling birds (Agbenohevi et al., 2015; Fatiregun & Saani, 2008), and low biosecurity compliance in LBMs where there is close contact of traders and customers with potentially sick birds are practices that increase the risk of transmission of HPAI to humans (Burimuah et al., 2016; Fasanmi et al., 2016; Fasanmi et al., 2017; Molia et al., 2016)

In the study on backyard farmers in northern Nigeria, more than half (57.7%) of the farmers reported that during outbreaks when they experienced massive bird deaths on their farms they still sold infected live birds. Few (14.1%) slaughtered and dressed the birds before sale and about a quarter (24.4%) of them mentioned that they slaughtered and consumed the birds with their family members (Musa et al., 2010).

Regarding preventive measures on poultry farms, most participants (81.4%) from a study in Nigeria stated that they always washed their hands as a general preventive practice. However, only 11.4% reported that they always used face masks, 10.7% reported always using gloves, 16.4% always used boots or boot covers, and 0.7% said they always used eye protection (Fatiregun & Saani, 2008). Gender disparities were observed in the practice of HPAI preventive measures. For instance, a study on poultry farmers in Ikorodu, Nigeria noted that about half as many females (24.2%) as males (43.9%) engaged in good preventive practice. Good preventive practice was defined as a score of more than 5 on a 9-item scale (Elelu, 2017). Other disparities were seen based on the level of education. Farmers with little or no education were significantly less likely to practice preventive measures than farmers with tertiary level education. Only 13.8% of farmers with no formal education, 1.6% of those with only primary education, and 19.7% of those with secondary education were likely to practice preventive measures compared to 32.8% of farmers with tertiary level education. Likewise, 49.6% of poultry farmers who had been in the profession for more than 3 years practiced good preventive measures compared to 2.5% of farmers in the business for 1-11 months, 3.3% of farmers in the business for 1-2 years, and 7.4% of farmers in the business for 2-3 years. (Elelu, 2017).

Psychosocial effects of HPAI outbreaks

Beyond the direct consequences of contracting HPAI infection, HPAI outbreaks have indirect psychosocial consequences. Fasina et al. (2010a) found that stress, anxiety, and depressive symptoms were associated with farmers in Nigeria whose poultry farms were affected during the 2006-2007 HPAI outbreak. Loss of income as a result of this outbreak affected entire families; the authors reported that low-income farmers who lost all their birds but found it hard to claim their losses from appropriate government agencies, received no compensation.

Reporting of suspected cases

Across the literature, reporting of suspected HPAI deaths in birds was low. The review showed only 37% of farmers in Nigeria mentioned that they had reported cases of dead birds to the veterinarian (Adam, et al., 2014). Similarly, the study of backyard poultry farmers in northern Nigeria showed that less than half of the farmers were willing to report avian influenza or the massive deaths of birds occurring within flocks to the designated authorities (Musa et al., 2010).

Barriers to engaging in healthy HPAI-related behaviors

Main barriers influencing non-compliance with recommended preventive practices include lack of vaccines (37%), lack of veterinary services (43.6%), as well as poor designs and inappropriate locations of LBMs that encourage close human-animal contact and do not support biosecurity compliance (Fasanmi et al., 2016).

In a study from Ghana (Odoom et al., 2012), there was widespread knowledge of HPAI; however, military troops and members of their families still practiced unsafe poultry handling, and reporting of bird deaths to veterinary officers was low. The researchers noted that awareness of the disease did not influence behavior change and described the need for efforts geared toward educating small-scale poultry farmers about how to minimize the risk of HPAI infection among bird populations and from birds

to humans, as well as strategies for increasing understanding about what to do with sick birds. Similarly, Paul et al. (2012) noted no change in the risk behaviors for HPAI practiced among a group of farmers in northern Nigeria despite their extensive knowledge of the transmission of the disease. In the study, the most commonly cited barrier to the practice of biosecurity measures by the farmers was the cost of the necessary equipment. The investigators suggested encouraging biosecurity measures like handwashing, which is a low-cost intervention that is unlikely to severely compromise the livelihood of the farmers. Furthermore, they described perceptions of low risk for HPAI among Islamic-educated farmers in Nigeria as a barrier to the practice of appropriate biosecurity measures. This group of farmers did not believe HPAI was either a dangerous or preventable disease and radio messaging was ineffective in reaching them. The investigators suggested advocacy campaigns at Islamic gatherings through imams as a potential strategy for this group of farmers.

Recommendations

The avian influenza virus has already adapted to several mammalian species; therefore, important preventive behaviors are those that reduce avian-human contact and the consequent adaptation of the HPAI virus in humans (Fasina et al., 2016). According to Fasina (2016), activities related to the production, processing, transportation, and retail of poultry should be the first line of defense. The author recommends safety practices in poultry farming under three broad categories: 1) limiting the contact of birds with humans and other animals; 2) ideal farm management practices including vaccination of poultry and proper management of sick and dead animals; and 3) hygienic farming practices including disinfection of the poultry premises with detergent and personal disinfection procedures like handwashing, hand sanitization, and overall sanitization (Fasina et al., 2016). With small-scale, free-range poultry farms, Alhaji & Odetokun (2011) recommend an emphasis on physical barriers to segregate humans and birds, together with cleaning and disinfection to protect poultry keepers against HPAI infection. They suggest that confinement of free-range flocks is not likely to result in a major reduction in HPAI risk levels. However, the authors noted that community-led initiatives may be necessary in areas where free-range poultry farming is widely practiced to protect the larger community from poor practices of bird owners.

To improve the adoption of preventive practices among farmers in Nigeria, Elelu (2017) proposed a participatory approach involving all poultry sector stakeholders for HPAI control. The author suggested that such an approach to developing control strategies would improve ownership and uptake of preventive measures among the high-risk groups because the participants would understand the benefits of the preventive measures. Elelu also noted that poultry farmers who had been in the business longer were more likely to adopt preventive measures compared to recent entrants into the poultry business. The researcher proposed that more experienced poultry farmers could be trained as advocates for HPAI prevention and then educate other farmers of the risk of HPAI. He suggested that poultry farmers may be more likely to adopt preventive strategies that were promoted by members of their community. Fasanmi et al. (2016) suggested that compensating farmers for culled birds would encourage the cooperation of LBM operators and support the voluntary reporting of outbreaks in the markets.

Surveillance and reporting measures are critical to prevent and control HPAI outbreaks. Lafond et al. (2014) suggested that reporting channels and reporting system requirements be clearly communicated to participating stakeholders, and efforts should be made to remove barriers to reporting. After the HPAI outbreak in Nigeria in 2016, physician training on HPAI was effective at increasing awareness of the country's reporting system among health care providers, regardless of clinical capacity, hospital type, or years of experience of the physicians (Lafond et al., 2014). Lafond et al. (2014) also found that most physicians surveyed in 2014 knew that HPAI was a reportable disease; however, despite the investments in training workshops and awareness of reporting, most physicians did not know the appropriate reporting channels or how to make a report. Furthermore, 93% of the physicians reported at least one obstacle to reporting within one of three main categories: 1) physician knowledge and perception; 2) physician time and resources; and 3) reporting system infrastructure. The authors also recommended improvements in the reporting of suspected HPAI deaths and outbreaks in birds; they suggested that community leaders who are trusted by farmers could play an essential role in communicating reports of suspected cases of HPAI.

Psychosocial effects of HPAI outbreaks on farmers should be considered during policy development and implementation (Fasina et al., 2010a). Providing technical, structural, financial, and psychosocial support to farmers who are directly affected by an HPAI outbreak may serve as a gateway for other awareness- and education-focused interventions.

Mass media is most useful in reaching poultry farmers and the general populace. The study by Adam, Qasim, and Kazeem (2014) among poultry farmers and live poultry sellers in Benin City, Nigeria revealed that the radio (57.7%) and television (82.5%) were the most frequently cited sources of HPAI-related information. The same study showed that other less effective sources of information about HPAI were newspaper (39.3%), colleagues (40.6%), place of worship (4.3%), seminars (22.2%), and health worker (20.1%). Similarly, Fatiregun and Saani (2008) showed that avian influenza knowledge scores were significantly higher among participants who had heard about HPAI through the mass media (74.3%) compared to those receiving information through other sources such as health professionals (9.3%), poultry workers association (7.9%), internet (7.1%) and schools (7.1%). Fatiregun and Saani noted however, that hearing about avian influenza from family and friends (27%), and an employer (20.7%) also were significantly associated with a higher knowledge score.

Brucella

Table 3. Summary of results, Brucella

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Brucellosis (cattle, dogs, camels)	Peer-reviewed articles (18) Reports (2)	Côte d'Ivoire (2) Ghana (1) Niger (1) Nigeria (13) Togo (1) Regional (2)	Livestock keepers Meat processors Meat consumers Dog owners Veterinarians	<u>HUMANS</u> Consumption of unpasteurized milk or undercooked meat Contact with aborted fetuses or vaginal or amniotic fluids Airborne contaminated particles <u>ANIMALS</u> Not vaccinating Introducing new animals into herds without quarantine, testing, or vaccination Sharing bulls Feeding cow fetuses to dogs	<u>HUMANS</u> Raise awareness Boil milk products Cook meat thoroughly Wash hands before and after milking Wear protective clothing when assisting with delivery/abortion and wash hands with soap afterwards Separate animals from living spaces <u>ANIMALS</u> Vaccinate Mineral supplementation Not mixing herds (with other species or other herds) Test and cull infected animals	Lack of knowledge of disease and risk factors Infrastructure of farms and living spaces leads to shared spaces between several types of animals and humans Cultural and culinary practices Lack of economic means to vaccinate

Brucellosis is an infectious disease caused by bacteria that can be present in cattle, sheep, goats, camels, horses, and dogs among other animals (Ehizibolo, 2011). In animals it may cause abortion, infertility, and decreased milk production (Mai, Irons, Kabir & Thompson, 2013). In humans it causes fever and debilitation and is fatal in 1 to 5% of untreated cases (Ducrotoy et al., 2014). Brucellosis is often misdiagnosed as malaria or typhoid fever (Adesokan, Alabi, Stack, & Cadmus, 2013). It is highly contagious and can be transmitted from animals to humans through contact of any skin abrasions with aborted animal fetuses or vaginal or amniotic fluids, the consumption of unpasteurized milk and dairy products and undercooked meat, or, less commonly, through the inhalation of airborne animal manure

particles (Ehizibolo, 2011). Animal-to-animal transmission occurs through mucus membranes following contact with infected materials, by inhalation, and *in utero* (Mai et al., 2013). There is an animal vaccine, but no human vaccine and no significant human-to-human transmission (Ducrotoy et al., 2017). Increasing demand for animal products, the intensification of livestock production, and movement of animals (pastoral systems) can increase the risk of brucellosis.

Screening tests for brucellosis include the Rose Bengal Plate Test (RBPT) which is the most affordable but also has a high rate of false-positives in small ruminants; the "modified RBPT;" and the indirect/competitive ELISA (Kanouté, Grangnon, Schidler, & Bonfoh, 2017). The different tests often result in different seropositivity results. The disease largely affects livestock and livestock keepers, meat processors and consumers, and dog owners.

Livestock and livestock keepers

Livestock keepers are the primary population that is at risk for brucellosis due to their close contact with cattle, sheep, and goats, the primary at-risk animal populations. We divide the discussion of risk factors for brucellosis transmission into risk factors for humans and risk factors for animals.

Among humans, the primary risk factors for contracting brucellosis include consumption of unpasteurized milk or undercooked meat; contact with amniotic fluids, placentas, and aborted fetuses; and inhalation of infected airborne particles (due to close physical contact between humans and animals). Many of the studies included in the review highlight these risk factors.

A study of brucellosis among 178 cattle farmers in Ghana found a seroprevalence of 10% and found several factors to be significantly associated with the likelihood of testing positive (Tasiame, Emikpe, & Folitse, 2016). Assisting cows during delivery, milking cows, not washing hands before or after milking cows, and consuming raw milk were significantly associated with the presence of brucellosis in humans (Tasiame et al., 2016). Young males between the ages of 11 and 20 engaged more frequently in these high-risk activities and were more likely to test positive.

A cross-sectional study involving 113 Fulani pastoralists and their herds of cattle in north-central Nigeria tested 672 cattle and found a cattle-level seroprevalence of bovine brucellosis of 1.9% and a herd-level seroprevalence of 9.7% (Alhaji, Wungak, & Bertu, 2016). These researchers identified drinking unpasteurized milk, eating infected raw meat, and handling aborted fetuses and placentas of infected animals as risk factors.

Only a few studies have explored determinants of risk behaviors like knowledge and risk perception. One very informative study among 222 cattle farmers in Senegal found that 68.9% of respondents did not know or had never heard of diseases that are naturally transmitted between animals and man (Tebug et al., 2015). Of those who had heard or knew of zoonosis, 94.2% named at least one zoonotic disease (N=69). Almost twenty-eight percent (27.5%) named rabies, 13% named bovine tuberculosis, 5.8% named mange, 2.9% named anthrax, 2.9% named ringworm, and 42% named disease symptoms like fever and diarrhea. No one named bovine brucellosis. Only 21.7% could name a mode of

transmission of zoonotic infection between animals and humans (Tebug et al., 2015). In terms of risk perception, only 11.3% of the farmers considered exposure to zoonosis during routine farm activities to be likely. Approximately twenty-nine percent (28.8%) said zoonosis is preventable and 33.8% felt close relatives had suffered from possible zoonotic infections such as tuberculosis in the past. One hundred eight out of 222 (48.6%) agreed that zoonotic infections could be a serious health hazard to humans in their community (Tebug et al., 2015). In terms of risk behaviors, 95% of participants drank fresh milk without prior heat treatment; 12.2% drank unpasteurized milk products; 70.3% assisted animals during parturition or abortion (among those, 98.1% neither used protective gloves nor washed their hands with disinfectants or soap after assisting animals); 89.6% disposed of aborted fetuses and dead animals on pastures and do not take special precautionary measures such as incineration or deep burial for aborted or dead fetuses (Tebug et al., 2015).

Other studies address only knowledge and behaviors. A study among 88 people in Côte d'Ivoire (mostly Fulani men), found that 90% had heard of brucellosis, 27% knew it could be transmitted to humans, 90% consumed raw milk, and 60% reported recurring fever (Kanouté et al., 2017). Four of the participants tested positive for brucellosis, but the sample was too small to test associations between risk factors and brucellosis in humans. Problematically, 50% of participants had disposed of aborted materials in public bodies of water (Kanouté et al., 2017).

Semi-structured interviews with 54 livestock keepers and 103 livestock marketers in southwestern Nigeria revealed that 73% of participants did not know what brucellosis was, 97% did not know its causes, 62% did not know its symptoms in animals, 95% did not know its symptoms in humans, and 65% did not know that it can spread from animals to humans (Adesokan et al., 2013). Adesokan et al. also found that among the livestock keepers, 100% drank fresh or soured cow or goat milk and shared living spaces with animals, 28% ate uncooked meat, 89% participated in milking, 43% participated in slaughtering, 11% handled aborted materials, and 78% moved cow dung. Among livestock marketers, 98% drank fresh or soured cow or goat milk, 12% ate uncooked meat, 64% shared living spaces with animals, 43% participated in milking, 85% participated in slaughtering, 82% handled aborted materials, and 79% moved cow dung.

Most of the studies about animals were conducted primarily regarding cattle. Risk factors for brucellosis include herding different species together (Kanouté et al., 2017; Mai et al., 2013), age (Boukary et al., 2012; Cadmus, Alabi, Adesokan, Dale, & Stack, 2013; Junaidu, Oboegbulem, & Salihu, 2011; Kanouté et al., 2017; Sanogo et al., 2012), herd size (Sanogo et al., 2012), location (Boukary et al., 2012), breed (Cadmus et al., 2013; Junaidu et al., 2011), sex (Junaidu et al., 2011), season (Junaidu et al., 2011), cattle production systems (trade, sedentary, or transhumant) (Boukary et al., 2012; Kanouté et al., 2017), introduction of new animals into herds (Cadmus et al., 2013; Mai et al., 2013), and borrowing or sharing bulls (Mai et al., 2013). Signs of brucellosis infection included history of abortion and retained placenta (Dean et al., 2013) and joint hygromas (Kanouté et al., 2017). Across the many studies, multiple risk factors are significantly associated with brucellosis infection.

In Côte d'Ivoire, a study of brucellosis among 907 cattle found a seroprevalence of 10.3% and significant associations with age and herd size (seropositivity more likely among cattle aged ≥5 years than cattle aged ≤3 years and in herds with more than 100 cattle) (Sanogo et al., 2012). Breed, sex, and locality were not found to be significantly associated (Sanogo et al., 2012). Herd size was interpreted by the authors to be related to high cattle density on pasture and age was interpreted to be related to increased accumulated chance of being exposed given that screening and culling strategies are not widespread in Côte d'Ivoire (Sanogo et al., 2012). Another study in Côte d'Ivoire by Kanouté et al. (2017) on 633 cattle and 622 small ruminants as well as 88 people found that brucellosis was present among 4.6% of cattle and that brucellosis seroprevalence was associated with age (cattle aged 5–8 years had greater odds of testing positive for brucellosis than cattle aged ≤4 years), joint hygromas (swelling over carpal joint in legs), sharing pastures with goats and sheep, and contact with pastoralist herds.

In Ghana, a study by Tasiame, Emikpe, and Folitse (2016) of 315 cattle found a seroprevalence of brucellosis of 23%. Having a history of abortion and ever having a retained placenta were significantly associated with testing positive for brucellosis.

In Niger, a study of 5,192 animals (goats, sheep, cattle) from 681 herds found a herd-level seroprevalence of brucellosis of 12.8% (urban), 11.2% (peri-urban) and 17.2% (rural) (Boukary et al., 2012). Seroprevalence was found to be associated with the urban/rural location, the size of herds (>50), the age of the animals, and transhumance (Boukary, et al., 2012).

In Nigeria, a study of 4,745 animals across 271 cattle herds in northern Nigeria found that the presence of sheep and/or goats on the same farm as cattle, buying three or more new animals in the previous year, integration of new animals into the herd without practicing quarantine, and borrowing or sharing bulls were all associated with increased odds of herd-level brucellosis, as well as increased numbers of animals that tested positive for brucellosis within the herd (Mai et al., 2013). In this study, herds that received mineral supplementation had significantly fewer animals that tested positive. In another large study in Nigeria of 1,547 cattle from 65 herds, 19.71% tested positive for brucellosis (Junaidu et al., 2011). In this study, age (older), sex (female), breed, and season (dry season) were significantly associated with seropositivity. A third study from Nigeria of 279 cattle found age (>3 years) and breed to be significantly associated with seropositivity, and sex, production system (trade or sedentary), and herd size not to be significantly associated (Cadmus et al., 2013). They recommend routine serological screening before introducing new animals into an existing herd.

In Togo, a study among livestock holders tested 683 people, 596 cattle from villages, 464 transhumant cattle, 465 sheep, and 221 goats for brucellosis and found the prevalence among humans to be very low (3–5 people, depending on the test) even though the majority of participants consume unboiled milk products (Dean et al., 2013). Prevalence among cattle from villages was 9.25% and among transhumant cattle, 7.3%. No prevalence was detected among sheep or goats. Adjusting for age, they found that cows that had aborted a fetus during the previous year were more likely to be positive for brucellosis. Sex and age were not predictors of seropositivity (Dean et al., 2013).

Finally, camels have been found to have *Brucella* antibodies in a study of 980 camels in northern Nigeria (Salisu et al., 2017). The authors attributed the infection to poor management practices, mixing camels with other species of livestock during grazing, and unrestricted movement of camels across international borders.

Other groups at risk for brucellosis

Other groups identified in the literature as at risk for brucellosis infection include meat processors and consumers, and dog owners. A study of bovine brucellosis in 8,105 cattle slaughtered over three years in Nigeria found an overall seroprevalence of 3.9% and that sex and breed were significantly associated with seropositivity (Akinseye et al., 2016). Also in Nigeria, the practice of consuming gravid uterus and the use of gravid uterus by traditional healers to induce labor and treat infertility and old age was associated with a lack of knowledge that eating undercooked contaminated gravid uterus can expose humans to brucellosis (Adesokan et al., 2013).

Several studies explored the prevalence of brucellosis in dog populations, highlighting the practice of feeding dogs fetuses and raw meat from slaughtered cattle and the close cohabitation of dogs with livestock. A study in southwestern Nigeria found brucellosis among 11.0% of 739 dogs tested (Ayoola, et al., 2016). Another study in Nigeria found a seroprevalence of 5.5% among a sample of 366 dogs (Cadmus et al., 2011). Eleven of the 20 positive dogs in this study had a history of being fed fetuses from cows. A third study of brucellosis in dogs in Nigeria found that presence of the infection was not significantly associated with age, sex, breed, or location (Momoh, Ijale, Ajogi, & Okolocha, 2014).

Prevention recommendations

In order to prevent the transmission of brucellosis between animals, authors recommend mass vaccination in cattle (Kanouté et al., 2017), mineral supplementation (Mai et al., 2013), quarantining or testing new animals before introducing to a herd (Mai et al., 2013), not mixing animals of different species (Kanouté et al., 2017; Mai et al., 2013), limiting contact with other animals or herds (Kanouté et al., 2017), and testing and culling potentially infected animals (Sanogo et al., 2013).

Recommendations also include treating fresh milk with heat before consumption and pasteurizing milk products, fully cooking meat, wearing protective gloves while helping animals during parturition or abortion, washing hands with disinfectants or soaps after assisting animals, and burying dead animals deep in the ground or incinerating them (Tebug, 2015).

Mycobacterium (Bovine Tuberculosis)

Table 4. Summary of results, *Mycobacterium* (bovine tuberculosis)

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
***Mycobacterium* (Bovine Tuberculosis)**	Peer-reviewed articles (7)	Ghana (2) Niger (2) Nigeria (3)	Livestock keepers Meat processors Meat consumers Veterinarians	<u>HUMANS</u> Consumption of unpasteurized milk or undercooked meat Contact with animal carcasses Airborne contaminated particles <u>ANIMALS</u> Introducing new animals into herds without quarantine, testing, or vaccination Sharing bulls Movement of cattle	<u>HUMANS</u> Raise awareness Boil milk products Cook meat thoroughly Wash hands before and after milking Wear protective clothing when slaughtering and processing meat and wash hands with soap afterwards Separate animals from living spaces <u>ANIMALS</u> Vaccinate Provide mineral supplementation Do not mix herds (with other species or other herds) Test and cull infected animals Discard carcasses with lesions (do not sell or consume)	Lack of knowledge of disease and risk factors Infrastructure of farms and living spaces leads to shared spaces between several types of animals and humans Certain cultural and culinary practices Lack of economic means to vaccinate

Bovine tuberculosis is contracted by humans through the consumption of undercooked and infected animal products, infected carcasses, and airborne particles (for example, in small shared spaces or from coughing cattle) (Boukary et al., 2011; Ehizibolo, Ehizibolo, Ehizibolo, Sugun, & Idachaba, 2011). Human-to-human transmission has not been confirmed (Hambolu, Freeman & Taddese, 2013). Bovine tuberculosis presents with symptoms similar to common tuberculosis and is often resistant to

tuberculosis treatment (Ehizibolo et al., 2011). Estimates for Africa suggest that 5–7% of human tuberculosis cases may be attributable to bovine tuberculosis, but data are incomplete (Hambolu et al., 2013).

Risk factors

Risk factors for bovine tuberculosis infection among humans include the consumption of undercooked meat or infected unpasteurized milk, close contact between humans and animals, poor hygiene practices on farms and slaughter houses, and an increase in the practice of animal husbandry in a given geographic area (Amemor et al., 2017; Ehizibolo et al., 2011). Strategies to mitigate the risk of transmission of bovine tuberculosis include testing and slaughtering infected animals, compensation for culled livestock, education and training of high-risk populations, mass vaccination of animals, restricting and controlling movement of animals, adopting hygienic processing and consumption practices for meat and milk, safe disposal of animal waste and improved by-product management, and improved collaboration between medical and veterinary sectors (Ehizibolo et al., 2011).

In Ghana, a study of 200 cattle found a seroprevalence of bovine tuberculosis of 19%. Among the potential risk factors considered, they found only kraal density to be significantly associated with seropositivity (Amemor et al., 2017). Age, sex, breed, and type of husbandry were not significantly associated with seropositivity and neither were cough/runny nose or having treated with antimicrobials. Sixty-eight herdsmen (mostly males between the ages of 11 and 20) were also tested with no positive results even though 89.7% consumed fresh milk, 83.8% did not wear protective clothing during herding and milking, and 70.6% shared bulls with other farms (Amemor et al., 2017).

In Niger, a survey of 51 households and 393 cattle over the age of 4 years found a prevalence of bovine tuberculosis among cattle of 3.6% (Boukary et al. 2011). In terms of risk behaviors, 68% of household heads said that their families consume exclusively unpasteurized milk, 51% said milking equipment was cleaned using well or creek water, and quarantine of new animals was practiced by only 25.5%. The only risk factor significantly associated with bovine tuberculosis, however, was the presence of animals coughing in the herd (Boukary et al., 2011).

Also in Niger, a longitudinal study of the presence of tuberculosis-like lesions in slaughtered animals in the abattoir of the capital Niamey found that the lesions were significantly associated with species (more prevalent in cattle and camels than in sheep or goats), the rainy season, the origin of the animals, female animals, and those of lower weight (Boukary et al., 2011). In terms of human risk factors, a survey of 1,131 randomly selected households (Boukary et al., 2012) found that across rural, peri-urban and urban areas, 65.7–92.1% of respondents did not control animal mating, 85.5–93.7% consumed unpasteurized milk, 0.5–1.4% used disinfectants to clean kitchen implements used to prepare food from animal products, 48.6–58.8% had observed animals in their herds with severe weight loss despite good diet, 18–27% had animals who had died after a persistent cough, and 22.8–43.1% knew people suffering from persistent cough.

A study of 1,360 cattle in Nigeria found a seroprevalence rate of bovine tuberculosis of 5.74% (Cadmus et al., 2010). In a multivariate logistic regression model, female sex, larger herd size, older age, and breed (*Bos taurus taurus* more susceptible than *Bos taurus indicus*) were significantly and positively associated with bovine tuberculosis. Another study in Nigeria (Okeke et al., 2016) found evidence of tuberculosis lesions on the carcasses of 11.2% of 52,262 cattle slaughtered between 2007 and 2012.

A third study in Nigeria used the Health Belief Model to explore the practice of eating infected lung among cattle meat handlers (Hambolu D, 2013). A total of 349 meat processors responded to demographic, knowledge, perceived severity, perceived susceptibility, perceived barriers, self-efficacy, and cue-to-action items.

In terms of risk behaviors, 88.8% of these respondents reported that they do not wear protective clothing when handling raw meat, 28.1% sell meat even if it has signs of contamination, 21.5% eat infected lung before selling, 14.3% eat raw meat before selling, and 14% do not wash hands after handling raw meat (Hambolu D, 2013). In terms of knowledge, 40.7% said that tuberculosis could spread from animals to humans through undercooked contaminated meat, contaminated milk (4.3%), and airborne particles (2.6%). In addition, 18.9% said that healthy looking meat can be infected, 34.11% that consumption of contaminated meat can be a source of bovine tuberculosis infection in humans, and 28.1% that consumption of infected lung is a source of bovine tuberculosis infection in humans. Across the knowledge questions, about 40% of participants responded, “don’t know.” In a multivariate logistic regression model, male gender, the knowledge that eating infected lung is a source of BTB infection in humans, and the belief that “I need to taste meat before selling to show that it is safe” were significantly and positively associated with consuming infected lung. Agreeing with the statement “I am at increased risk of contracting BTB when I don’t wash my hands after handling carcasses” was significantly and negatively associated with consuming infected lung. Participants felt that educational programs, free protective clothing, adequate compensation for cooperation, government-imposed penalties, and television and radio advertisements might help change behavior (Hambolu D, 2013).

Lopez (2016) suggests that low bovine tuberculosis prevalence in parts of the world can be attributed to surveillance activities including testing of meat, tracing back carcasses where bovine tuberculosis is suspected, condemning infected carcasses or organs, restricting the movement of infected herds, periodic testing and slaughter or segregation, pasteurization of milk, and restriction of breeding (Lopes, 2016). Some countries in West Africa, such as Ghana, have put many of these policies in place, but enforcement is lacking (Lopes, 2016). An evaluation of the bovine tuberculosis surveillance system in the greater Accra area found that the system was able to detect some cases (through testing meat and targeted screening), but that the system was far from fully functional. Challenges to the surveillance system include irregular allocation of funds and a lack of a specific budget for bovine tuberculosis, inadequate staffing, inadequate infrastructure (testing locations, data systems), limited ability to enforce slaughter of infected animals, limited ability to trace infected carcasses back to the herd, limited surveillance of private farms, and refusal of testing of carcasses among butchers (Lopes, 2016).

Recommendations

Recommendations for limiting the spread of *Mycobacterium* include investing more resources, increasing awareness among farmers and key stakeholders, offering compensation to farmers whose animals test positive, training all veterinary officers, creating databases of cattle farms by district, and testing animals used for breeding (Lopes, 2016).

Plague

Plague is an infectious disease that is caused by *Yersinia pestis* bacterium, commonly found in rodents. It is spread by flea bites from an infected animal, from handling infected animals (bubonic or septicemic plague), or through airborne droplet particles (pneumonic plague) coughed or sneezed near a person. Transmission can also occur through direct physical contact with an infected person, through indirect contact such as touching contaminated soil or another contaminated surface, or by fecal-oral transmission—usually from contaminated food or water sources.

Eight articles were returned in the search for plague. None of the articles met the criteria for inclusion in the literature review and report.

Rabies

Table 5. Summary of results, rabies

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Rabies (dog, cattle, pig, human)	Peer-reviewed articles (11) Reports (3)	Côte d'Ivoire (1) Ghana (1) Mali (3) Nigeria (6) Sierra Leone (1) Regional (2)	General public Dog owners Children/parents Health care workers Traditional healers Veterinarians	Dog bites Dog meat processing and consumption	Mass canine vaccination campaigns Awareness campaigns	Lack of knowledge of where and when to vaccinate Cost of vaccinating dogs Availability of vaccination points—taking dogs to the veterinarian takes time, is inconvenient (transporting animal), and costly Stray dogs

Africa is the continent second-most affected by rabies with an estimated 14,160 (36%) of the 59,000 global rabies deaths each year (Mauti, 2017). In Africa, rabies is primarily transmitted by dog bites and many of the victims are children (Eke, Omotowo, Ukoha, & Ibe, 2015). Treatment for rabies requires timely post-exposure vaccination (before the bite victim exhibits any symptoms) and, in cases of severe exposure, rabies immunoglobulins (RIGs) (Dodet et al., 2008). Most West African countries import cell culture vaccines, however the vaccines (especially RIG) are not always available and may be unaffordable for some patients as they are subsidized only in a few West African countries (Dodet et al., 2008).

The literature is comprised primarily of studies and interventions focused on the control of rabies among dogs and among humans. Two additional studies (Suluku et al., 2017; Tasiame, 2016) discuss rabies in pigs and cattle following dog bites and the risk of transmission to humans when the meat from infected animals is consumed; however, these are not discussed in detail here.

Among dogs, rabies control efforts reflected in the literature include information and education programs, mass vaccination campaigns, and promotion of safe consumption of dog meat. The literature includes discussion of populations of stray dogs as a problem, but none of the interventions directly addressed stray dogs.

Mass canine vaccination campaigns

Lavan, King, Sutton, and Tunceli (2017) argue that canine vaccination is the most cost-effective strategy to control human rabies exposure in rabies-endemic areas. Rabies control experts recommend achieving 70% vaccination among domestic dog populations in order to greatly reduce or even eliminate the incidence of rabies (Lavan et al., 2017). One stand-alone study two implementation evaluations conducted in Bamako, Mali, shed light on the communication and implementation challenges associated with raising vaccination coverage among domestic dog populations.

The stand-alone study, a cross-sectional survey of 2,956 households in Bamako indicated that 90% of respondents were aware of rabies, biting and change in behavior were the most commonly cited signs of rabid dogs, and the most frequent response was to kill the dog (Mauti, 2017). Sixty-five percent of non-dog owners and 81% of dog owners were aware that vaccination of the dog can prevent rabies, but only 29% of dog owners were aware that dogs should be first vaccinated against rabies at 3 months of age (Mauti, 2017). Forty-five percent of the 306 dogs in households surveyed were reported to be vaccinated at least once, but only half had a valid vaccination card. The primary reasons cited for non-vaccination were cost (31%), negligence (15%), thought the vaccine was useless (14%), and lack of knowledge (11%) (Mauti, 2017). This study suggests that although awareness of rabies and of rabies vaccinations may be high, awareness alone may be insufficient to prompt dog owners to vaccinate their dogs; price of the vaccination and inconvenience may be barriers.

The two free central-point mass canine vaccination campaigns also took place in Bamako (Muthiani, Traoré, Mauti, Zinsstag, & Hattendorf, 2015; Mosimann et al., 2017). The first resulted in only an estimated 17% coverage due to lack of information (25%), inability to handle the dog (16%), or no clear reason (37%) (Muthiani et al., 2015). The authors concluded that there was a need to improve the implementation and communication around the mass canine vaccination campaign. A follow-up free central-point canine rabies vaccination campaign was implemented and evaluated through a mixed-methods evaluation (Mosimann et al., 2017). The campaign broadcast radio announcements to increase awareness and risk perception and communicate the details of the vaccination campaign. Messages were also transmitted through town criers, neighborhood chiefs, mosques, and government veterinary services. During the five-day campaign, 429 dogs were vaccinated, but estimated vaccination coverage reached only 27% and 20% in the two participating communes. According to Muthiani et al., (2015) and Mosimann et al., (2017), the primary reason for non-participation was that dog owners were “not informed.” In general, households closer to the vaccination points were more likely to participate. Some participants suggested informing people through short text message (SMS) and door-to-door campaigning. One-third of the people who did participate in the vaccination campaign were informed by another person, highlighting the importance of word-of-mouth.

In 2017, the Sierra Leone One Health zoonotic disease prioritization exercise ranked rabies as the 2nd most important priority zoonotic disease. The literature is sparse on the behavioral factors that drive the transmission of rabies in Sierra Leone. A few studies, however, cover the ecology of the dog population in Sierra Leone and dog-human interactions.

Sierra Leone has one of the densest populations of stray dogs in the world, and in Freetown there are an estimated 100,000 stray dogs (World Animal Protection, 2018). A majority of dog owners that participated in a study conducted by Suluku et al. (2012) in Freetown stated that they spent next to nothing financially on their pets. Feeding their pet dogs is not a high priority for many dog owners which may explain the large number of stray dogs that roam around garbage dumps in Freetown (Suluku, Abu-Bakarr, Johnny, & Jonsyn-Ellis, 2012). In the first quarter of 2018, there were 327 recorded animal bites across the country (SL MOHS, 2018), however this number may be an underestimation from poor reporting and surveillance (MOAFFS & MOHS, 2015). The alarming number of animal bites raises concerns about the transmission of rabies in Sierra Leone as dogs are the primary reservoir of rabies in Africa (Suluku et al., 2012).

To manage the dog population problem in Freetown, the Freetown City Council partnered with the Sierra Leone Animal Welfare Society (SLAWS) to spay, neuter, and vaccinate dogs against rabies at no charge to dog owners. So far, the society has vaccinated about 50,000 dogs and sterilized over 45,000 dogs. Success of the program is hampered by a lack of knowledge of rabies in the community and low awareness of the program. In 2008, a study on dog owners in Freetown reported that only 55% of study participants had taken their dog to receive the free vaccination provided by SLAWS (Suluku et al., 2012). Non-compliant participants neglected to vaccinate their dogs due to their lack of knowledge about rabies (74%) and their lack of awareness about the program (26%). There is little information on the availability and cost for human rabies vaccination in Sierra Leone within the published peer review or grey literature.

These interventions and accompanying evaluations suggest that even when the vaccine is free, not all dog owners will take the time to bring their dogs to a central vaccination point. Door-to-door vaccination campaigns might be more successful as there are indirect costs to dog owners in terms of time/income even when the vaccination is free. Alternatively, scheduling the vaccination campaign during school holidays might be successful as many of the dogs were brought to the vaccination point by children. The vaccination was generally found to be acceptable to dog owners, and dog owners who vaccinated reported doing so to protect the safety of family members and neighbors, for the dog's well-being, and to avoid problems in the case of a dog bite.

Trade and consumption of dog meat

In Nigeria, the trade and consumption of dog meat generates risk factors for rabies stemming from a lack of awareness of the availability of human anti-rabies vaccines, low vaccination coverage in dogs, lack of protective gear among dog meat processors, dog bites, and exposure of cuts to saliva and brain tissue during dog meat processing (Ameh, Dzikwi, & Umoh, 2014).

Through interviews with a convenience sample of 49 dog meat processors and 111 dog meat consumers, a study in Kaduna State, Nigeria, found that 28% of respondents thought that rabies "cannot kill," 37.5% thought that "slaughterers and processors of dog meat are at risk of rabies," and 63.8% thought that "rabid animal can be consumed" (Odeh, Umoh, & Dzikwi, 2013). This study found that education was associated with greater rabies knowledge. In addition, 154 brain samples from slaughtered dogs showed a 3.9% prevalence of the rabies antigen.

In the Ameh, Dzikwi, and Umoh (2014) study related to the dog trade in Nigeria, the authors sampled 188 dog brains (purchased from dog meat vendors) and found that 7.98% were positive for rabies antigen. They found also that education and occupation were significantly and positively associated with rabies knowledge among 200 dog owners in Nigeria.

The authors of a study about the dog meat trade in Nigeria recommended regulation of the trade, the vaccination of dogs, public awareness campaigns, and that dog meat processors take the pre-exposure rabies prophylaxis and wear protective clothing (Ameh et al., 2014).

Rabies in humans

Among humans, the literature reflects a focus on raising awareness among the population and health care professionals regarding the risk of exposure and timely treatment. According to a report drafted by rabies experts from 14 francophone African countries, people who are exposed to rabies do not seek treatment either because they are not aware of the risks of rabies or because they live in rural areas, too far away from rabies prevention centers where the vaccine is available (Dodet et al., 2008). In addition, bite victims often consult traditional healers and seek medical help when it is too late (Dodet et al., 2008; Dzikwi, Ibrahim, & Umoh, 2012; Eke et al., 2015). In the case of timely care seeking, the availability and cost of the vaccine can present barriers to access.

The literature recommends public awareness campaigns around vaccinations, the danger of dog bites, appropriate first aid, and where to seek care. The public should be educated about responsible dog ownership (Eke et al., 2015) and laws around dog vaccination should be enforced (Dzikwi, et al, 2012). Children, often victims of rabies, should be educated not to play with stray dogs, and parents and teachers should be taught to wash bites immediately with soap and water, seek immediate medical care, and report biting dogs to a veterinary clinic (Dzikwi, et al., 2012). Rabies experts proposed that "Thorough washing of the wound for a minimum of 15 minutes with soap and water, detergent, or iodine can prevent or reduce the risk of infection by eliminating or inactivating the virus" (Dodet et al., 2008). Others propose training at all levels of health care for treatment of dog bites (Eke et al., 2015), including common "first responders" like roadside medicine vendors, traditional healers, and pharmacists (Ekanem et al., 2013).

Summary

The literature suggests there is a need for public awareness campaigns around dog vaccinations (legal responsibilities, cost, location, timing, and frequency of vaccinations), the danger of dog meat processing and consumption, the danger of dog bites, proper first aid, where to seek treatment, timely treatment seeking, and the fatality of rabies (Dodet et al., 2008; Mauti, 2017; Mosimann et al., 2017; Muthiani et al., 2015). Barriers to dog vaccination may include lack of knowledge, cost, and inconvenience (Mauti, 2017). Barriers to proper first aid and timely treatment seeking may include lack of knowledge of risks, where and when to seek treatment, distance to treatment centers, the availability and cost of the vaccine, and the level of training of medical professionals (Dodet et al., 2008. Finally, a barrier to the visibility of rabies in West Africa is the lack of data as many rabies deaths likely go unreported (Dodet et al., 2008); a barrier to mobilization is the lack of coordination between the veterinary and public health sectors (Okello, 2015).

Salmonellosis

Table 6. Summary of results, salmonellosis

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Salmonellosis	Peer-reviewed articles (7)	Burkina Faso (2) Ghana (1) Nigeria (2) Senegal (2)	Poultry, cattle, and swine farmers Butchers Abattoir workers General public	<u>HUMANS</u> Hygiene control along meat retail chain Consumption of eggs from plastic egg crates Consumption of unfermented soft cheese <u>ANIMALS</u> Poor biosecurity measures Membership of farm in a poultry association More than 1-kilometer distance from landfill and other farms Mixed poultry housing system Proximity of other carriers, infected animals, and pests.	Health communication (education) Strict biosecurity measures Prevent cross-contamination-Use new utensils after manipulating fresh meat	Lack of refrigerators to store meat at low temperatures at home

This section includes seven articles including two from Burkina Faso (Kagambèga, Haukka, Siitonen, Traoré, & Barro, 2011; Kagambèga et al., 2013), two from Nigeria (Fagbamila et al., 2018; Folorunso, Kayode, & Onibon, 2013), two studies from Senegal (Missohou et al., 2011; Pouillot et al., 2012) and one study from Ghana (Parry-Hanson Kunadu, Holmes, Miller, & Grant, 2018) that examine various aspects around the transmission, risk factors and determinants of salmonellosis across West Africa.

Kagambèga et al. (2013) identify salmonellosis as an important zoonotic disease worldwide and the primary animal sources of *Salmonella* infection in humans as infected cattle, poultry, and swine. Kagambèga et al. (2013) found that in Burkina Faso, *Salmonella* was present in the feces of 52% of the cattle, 55% of the poultry, 16% of the swine, and 96% of the hedgehogs sampled. The presence of

Salmonella in hedgehog feces is important because hedgehogs are hunted at night and eaten by villagers in Burkina Faso and during the rainy season, the feces of animals including hedgehogs can pollute the water sources such as rivers and wells (Kagambèga et al., 2013). *Salmonella* outbreaks are more commonly associated with contaminated poultry, eggs, and meat (Kagambèga et al., 2013). *Salmonella* bacteria cause a variety of illnesses from mild to severe invasive forms of gastroenteritis and bacteremia (Kagambèga et al., 2013; Parry-Hanson Kunadu et al., 2018).

Risk factors for *Salmonella* infection in animals

Poor biosecurity practices on farms encourage the introduction and transmission of *Salmonella* in farm animals (Fagbamila et al., 2018; Folorunso et al., 2013). A nationwide survey of layer farms in Nigeria showed that poor hygiene measures for farm visitors, including inadequate protections for shoes, clothing, and hands, were shown to increase the risk of *Salmonella* infection in commercial poultry farms (Fagbamila et al., 2018). In addition, increased movement of visitors and staff on and off farmland was shown to be a risk factor for the introduction of *Salmonella* infection on such farms.

The risk of *Salmonella* contamination was increased in poultry meat from farms less than 1 kilometer from landfills compared to farms more than 1 kilometer from landfills (Missohou et al., 2011). Similarly, Fagbamila et al. (2018) found that farms that were over 1 kilometer away from the nearest farm were associated with increased *Salmonella* risk. The authors hypothesized that the reason was that farmers close to each other paid more attention to manage the risk of *Salmonella* spread.

The type of poultry housing was associated with risk of *Salmonella* on farms. Mixed housing systems on poultry farms, such as the use of both battery cage and deep litter systems, were shown to have an increased risk of *Salmonella* infection compared to those that practiced only one system (either only battery cage or only deep litter system), possibly because the farmers reported that it was more difficult to clean mixed housing systems (Fagbamila et al., 2018).

Other risk factors for *Salmonella* infection on farms identified by Fagbamila et al. (2018) include links to non-governmental support organizations and the use of contaminated equipment. Poultry farmer membership in the Poultry Association of Nigeria, a non-governmental support organization, was shown to present with increased risk of *Salmonella* on the farms of members compared to farms of non-members of the non-governmental organization (NGO). The researchers proposed the sharing of farm equipment among members of NGOs as a possible reason for increased risk of *Salmonella* infection among poultry that belonged to these farmers (Fagbamila et al., 2018).

Oddly, the national survey on commercial laying hen farms in Nigeria reported that regular contact by a health worker was associated with increased odds of farm infection with *Salmonella*. However, the authors noted that regular contacts by a health worker could be indicative of an ongoing or persistent infection on the farm that requires frequent monitoring (Fagbamila et al., 2018).

Finally, Fagbamila et al., reported that the presence of carriers such as wild birds, rodents, and insects, as well as contaminated litter, water, dust, equipment, and animal feed have been shown to influence *Salmonella* introduction and transmission among farm animals and poultry in other African countries outside West Africa (Fagbamila et al., 2018).

Risk factors for *Salmonella* infection in humans

Kagambèga et al. (2013) found that the defective hygiene control in the meat retail chain and the high *Salmonella* carriage rates of animals were major risk factors for *Salmonella* infection in Burkinabés.

In Dakar, Senegal, a risk assessment showed that cross-contamination of hands and kitchen equipment was the most important risk factor for *Salmonella* infection in homes (Pouillot et al., 2012). Other factors that increased the risk of *Salmonella* infection in homes included storing chicken at higher than optimal temperatures, and the authors noted that many homes sampled in Dakar did not have a refrigerator (Pouillot et al., 2012).

In Nigeria, plastic egg crates were found to have higher risk of presence of *Salmonella* infection than paper egg crates because the plastic crates tend to stay longer on the farms and therefore carry an increased probability of being infected with *Salmonella* (Fagbamila et al., 2018). These authors noted that consumption of contaminated or undercooked eggs and other poultry products was associated with the risk of *Salmonella* infection in humans in Europe and other parts of Africa. (Fagbamila et al., 2018).

Consumption of unripened soft cheese without further lethal heat treatment is a probable risk factor for invasive non-typhoidal *Salmonella* infection. The presence of the multidrug-resistant *Salmonella enterica* serovars Muenster and Legon were identified in 11.8% and 5.9%, respectively, of unfermented cheese samples purchased from traditional milk markets in Ghana (Parry-Hanson Kunadu et al., 2018).

The general public is at risk for *Salmonella* infection, but poultry, cattle, and swine farmers, as well as abattoir workers and meat sellers, are more vulnerable due to cross-contamination that may occur in their everyday interaction with infected meat and meat products. The process of removing the gastrointestinal tract of food animals is one of the most important sources of carcass and organ contamination at abattoirs (Kagambèga et al., 2013).

Behaviors and practices that increase the risk of *Salmonella* infection

Salmonella is mainly disseminated by trade of animals and uncooked animal food products (Kagambèga et al., 2013). In Burkina Faso, researchers reported that the hygienic practices of meat sellers did not meet optimum standards for the handling of meat and meat products and encouraged the contamination of meat with *Salmonella* (Kagambèga et al., 2011). As described by Kagambèga et al., meat was transported from slaughterhouses to local markets partially wrapped or not wrapped at all on bicycles or motorcycles and in cars without refrigeration. Furthermore, meat sellers carried the carcasses on their shoulders and meat was sold off their tables in ambient temperatures. The sellers hardly ever washed their hands, never wore protective clothing, and did not use adequate amounts of water to clean their tables or cutting tools (Kagambèga et al., 2011).

Recommendations

Farming practices that may reduce the risk of *Salmonella* infection and its transmission include the cleaning and disinfection of poultry houses, provision of farm worker access to toilets, farm work clothing, and handwashing facilities (Fagbamila et al., 2018). More hygienic animal slaughtering practices and food preparation are also recommended to reduce the burden of salmonellosis (Pouillot et al., 2012).

Pouillot et al. (2012) suggested that the most important mitigation strategies at home were those for preventing cross-contamination such as thoroughly cleaning the cutting board, knife, and dish after manipulating uncooked chicken rather than rinsing or lightly washing used equipment, and preventing the contamination of dish towels, faucets, and other kitchen equipment.

The study among meat sellers in Burkina Faso demonstrated that there is a need to increase awareness of environmental and personal hygiene issues among meat vendors (Kagambèga et al., 2011).

Viral Hemorrhagic Fevers

Ebola Virus Disease

Table 7. Summary of results, Ebola virus disease

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Ebola Virus Disease	Peer-reviewed articles (20) (Includes 1 multi-country source covering 2 countries)	Sierra Leone (7) Liberia (2) Nigeria (6) Guinea (1) Ghana (4) Benin (1)	General public Hunters Bushmeat handlers Students Health care workers	Handling and butchering infected animals Consumption of bush meat Direct or indirect contact with bats Contact with infectious persons/corpses		Blackmail/threat surrounding hunting laws Belief that there was no threat because hunting/eating wild animals had been done for many years

Ebola virus disease (EVD) is a severe and often fatal illness. The largest Ebola virus epidemic took place from 2014 to 2016 in West Africa and resulted in over 28,600 cases of EVD and 11,300 deaths in Guinea, Liberia, and Sierra Leone (Ordaz-Neameth et al., 2017). While the origin of the virus is unknown, evidence suggests that fruit bats, apes, and chimpanzees are most likely the host of the Ebola virus (Adongo et al., 2016). This zoonotic disease is transmitted to humans through contact with blood and other bodily fluids of infected wildlife such as fruit bats, forest antelope, and non-human primates (Ordaz-Neameth, 2017). EVD Infections also can be transmitted between humans through direct contact with broken skin, mucous membranes, or other bodily fluids or secretions (Adongo PB, 2016).

Risk factors

Although the index case of EVD during the 2014 outbreak was due to contact with bats, human-to-human transmission of EVD was the most critical driver of the two-year long epidemic in Sierra Leone (Wilkinson & Leach, 2015). The primary cultural and behavioral practices that drive the human-to-human transmission of EVD include the washing and transporting of dead bodies for burials and close human contact with sick individuals when their relatives provide them care (Richards et al., 2015). Based on evidence from the EVD epidemic, women were most at risk for EVD because of their role caring for the sick within the family. Children had the lowest risk for EVD because of their lower exposure to sick family members compared to adults, as they are often deliberately kept away from the sick and also not involved in burial practices (Bower et al., 2016). Risk behaviors associated with animal-to-human

transmission of EVD include contact with bodily fluids of bats, fresh bush meat, and consumption of fruits half eaten by fruit bats, the natural reservoirs of the EVD.

Risk factors for EVD among humans include handling or butchering infected animals such as bats, antelopes, and non-human primates, as well as consumption of bushmeat (Bonwitt et al., 2018; Ordaz-Neameth, 2017). Gbogbo (2017) cites direct contact with bats, consumption of fruit near bat colonies and use of rainwater near such colonies as risk factors. Many cases of EVD resulted from direct contact with infected persons and from cultural practices associated with the dead during homecare, health care, and traditional burial preparations, including through contact with the blood of deceased persons (Irwin, 2017). There is limited information regarding sexual risk behavior and EVD (Abad, 2017). There are currently no approved antiviral drugs or vaccines for EVD, although there are various experimental treatments and vaccines currently being trialed for safety and effectiveness (Iliyasu, 2015).

Knowledge, attitudes, and practices

Several studies explored knowledge, attitudes, and practices of EVD risk behaviors among priority populations in Sierra Leone, Ghana, Nigeria, Guinea, and Benin.

In 2015, a study of 466 participants from the Western Area Rural District in Sierra Leone found that only a small number of respondents (10%) believed they were at risk of Ebola due to lack of adherence to medical rules, and 98% believed the primary mode of transmission of the virus was through participation in a traditional funeral. Knowledge of other modes of transmission included patient semen (89%) and breast milk (89%). Nearly all respondents (98-99%) reported that since learning about Ebola, they had avoided certain risk behaviors, such as contact with blood or body fluids, and attending traditional burials (Jiang, 2016).

A study of EVD public health messages in Sierra Leone found that messages focused predominantly on the risk from contact with wild animals through consumption or hunting of their meat, and through the consumption of fruits that animals had contact with or had eaten (Bonwitt et al., 2018). In this study, no messages regarding warnings about contact with wild animals that were sick or dead were reported. All 46 study respondents were aware of wild mammals as a mode of transmission for EVD, however, they lacked knowledge and clarity about the specific species of animals that could transmit EVD; such responses ranged from bats to non-human primates, brush-tailed porcupines, and duiker antelopes. Respondents did not believe that consumption of wild meat could cause a health risk, and many stated that wild animals had been hunted and eaten for many years without causing an epidemic in humans. Those respondents who believed that EVD and consumption of wild meat were linked practiced various strategies to mitigate their perceived risk of infection: some only avoided the animals they thought were a risk for EVD, while others reported that they used cooking methods (frying, boiling) and certain ingredients (spices, palm oil) as a way to “deactivate” any EVD that may have been present in the wild meat.

Another study in Sierra Leone by Vygen, et al. from May 2014 to February 2015 described health-seeking behavior before death or during a recent illness before, as well as during, the recent Ebola outbreak. A household survey of 4,943 individuals reported a decrease in use of health facilities for care. The study showed that 58.1% of individuals who had experienced illness during the Ebola epidemic had first sought care at a health facility, which was a decrease from 85.9% before the Ebola epidemic (Vygen, 2016).

Finally, a study conducted by Carter et al. (2017) of 350 individuals and 108 community health volunteers (CHVs) reported several reasons for reluctance to seek treatment for EVD. Seventy-seven percent of community members reported that fear, most commonly fear of ambulances and/or not knowing what takes place inside treatment centers, made them reluctant to seek such treatment. Respondents also feared what would happen with their body after death and, if they were far from home when they died, whether important cultural burial practices would be respected. Finally, distance to treatment centers also increased the barriers for community members to seek treatment for EVD. While there had been some changes that were acknowledged and reported by CHVs and community members, not all attitudes had changed. For their part, CHVs stated that they felt sidelined by "outsiders" when government support arrived despite their early efforts to screen new entrants to the community for EVD.

Encouragingly, awareness of EVD was associated with changes in people's behaviors; nearly all respondents (98–99%) reported that since learning about EVD, they had changed certain risk behaviors, such as avoiding contact with blood and body fluids, and not participating in rituals associated with traditional burials (Jiang, 2016). However, myths and misconceptions related to prevention programs and the response effort also influenced care-seeking behaviors during the Ebola epidemic. During an EVD vaccine trial, participants described rumors that the vaccine was a form of "slow poison" that could give recipients Ebola. Rumors related to blood, discomfort of giving blood, and the fear that blood leaves one permanently weak were also reported by both participants and non-participants in the vaccine trial (Tengbeh, 2018).

Bonwitt et al. (2018) conducted a study on the consequences of a ban on hunting and eating wild meat that was enacted during the height of the EVD outbreak. This study highlighted several important lessons for public health emergency response and preparedness programs. It noted that messages communicated following the ban on hunting of wild meat focused predominantly on risk incurred from contact with wild animals through consumption or hunting of their meat, or consumption of fruits that wild animals had touched or partially eaten. The focus on consumption of wild meat contradicted the experiences of the majority of the public who had consumed wild meat without any incident. Moreover, there were no warnings reported against contact with wild animals that were sick or dead. Consequently, there was a proliferation of informal trade networks for bush meat, and this hampered the prevention response strategies for zoonoses. Further, the criminalization of consumption of bush meat fueled fears and rumors within communities with EVD outbreaks, in turn entrenching distrust and exacerbating pre-existing tensions with government and health authorities. Bonwitt et al. (2018)

suggested that health communication messaging regarding the risks surrounding consumption of bush meat should fully take into account the significance of hunting to local livelihoods, and include communicative engagement approaches that are designed, validated, and continually refined for emergency situations.

In Nigeria, a study conducted by Iliyasu et al. (2015) with 880 participants among the general population and health care workers in the states of Kano, Bayelsa, and Cross River found several gaps in knowledge, attitudes, and practices regarding EVD. Only 50% correctly defined EVD as an infection caused by a virus; however, the majority of respondents correctly associated EVD with bats, monkeys, and wild animals. Most participants were aware of the ways the virus is transmitted such as through bodily secretions (Kano: 91%, Bayelsa: 99%, Cross River: 100%) and blood (Kano: 90%, Bayelsa: 99%, Cross River: 91%); however, there were some respondents who believed that EVD is transmitted by breathing infected air (Kano: 42%, Bayelsa: 30%, Cross River: 12%). The Iliyasu et al. study showed that the predictors of "good knowledge" of EVD included: being a health care worker, having a moderate to high fear of EVD, and a willingness to modify old habits.

Kaoje, et al. (2016) explored awareness, knowledge, and misconceptions of EVD among 433 rural residents in Nigeria. The authors strongly suggest that efforts to clarify myths and misconceptions about EVD should be focused on community-level interventions such as community dialogues, mass media campaigns involving community and religious leaders, and development of messages based on the sociocultural context of the target audience. The study suggests that a surveillance system to monitor rumors and misconceptions could guide message development to address common beliefs that may deter preventive efforts for EVD in communities. Another study from Nigeria (Gidado et al., 2015) found that 33% of the 5,333 respondents did not know the cause of EVD, while respectively, 17%, 11% and 6% knew that infection from non-human primates, bushmeat, and bats causes EVD. Sixty-six percent knew that regular hand washing with soap and water was an effective way to prevent the spread of EVD, and 46% knew to avoid contact with an individual with suspected or confirmed EVD. Sixteen percent avoided eating bushmeat and only 5% knew not to participate in the burial rituals of someone who had died from EVD.

A study in Nigeria addressed the gap in knowledge, attitudes, and practices of college students related to health communication messages on EVD delivered through public service announcements. A total of 77.3% of college students surveyed agreed that survival is very unlikely after contracting EVD. Eighty-six percent thought that EVD could be contracted through bodily secretions of a sick person, and 61% thought it could be contracted through close contact with an infected person. Eighty-two percent agreed that regular handwashing and hand sanitizers could prevent the transmission of Ebola. The study also identified areas that could benefit from more information about EVD. Specifically, there were still many misconceptions about the causes and means of transmission of EVD: while nearly 78% were aware that consumption of wildlife is a source of EVD, 60% thought that Ebola was an airborne disease. Nearly 77% of the students agreed that Ebola had been completely eradicated in Nigeria (Ajilorea, Atakiti, & Onyenankeya, 2017).

A study by Olowookere et al. (2015) of health workers' knowledge, attitudes, and practices toward EVD in Nigeria found that over half of the respondents (58%) had poor knowledge of EVD. Ninety-three percent of participants knew that EVD was caused by a deadly virus, and a majority knew that EVD could be transmitted from person-to-person (88%) and from animal to person (86%). However, while the majority of participants knew that EVD could be transmitted through bodily fluids, less than half (46%) knew that the virus penetrates broken skin. While most respondents were aware of the EVD epidemic in West Africa (85%), some still were not aware of it. At the time the study was conducted, no EVD cases had been reported in Nigeria and most respondents perceived EVD as something that was "too far away" to be very relevant.

In Guinea, a study by Irwin et al. (2017) of 5,752 participants found that the vast majority (91.4%) of participants had heard of EVD; however, only 20% cited a virus as the cause of EVD. Fifty-five percent believed that wild animals caused EVD, 55% cited wild game or contaminated fruit, 66% cited contact with ill persons or their bodily fluids, and only 4% cited funeral participation involving contact or washing of a dead corpse as risk factors for EVD. Nearly all participants (95%) reported they took actions such as handwashing or avoiding ill people in order to avoid EVD. Of the participants who rated their risk of acquiring EVD, 82.7% felt that they had no or low risk of contracting the disease. The most frequently cited source of Ebola-related information during the epidemic was mass media (84%) such as radio, television, newspaper, or internet.

In Ghana, a study by Adongo et al. (2016a) of 235 respondents found that while ceremonies and rituals varied between ethnic cultures and geographic areas across the country, funeral practices were a very important cultural tradition for all the ethnic groups. However, high-risk traditional funeral practices could result in health workers and family members having a greater risk of infection of EVD through direct contact with infectious fluids from dead bodies. In many communities, a person who died a natural death was bathed at home by family members as a sign of honor and respect for the dead. The study found that bathing was often done without any type of protection and attempts to protect oneself through the use of skin barriers was considered to be disrespectful and dishonorable. An exception to this occurred when the deceased was sent to a funeral home for burial preparation. Burial preparation was perceived by the EVD response team members to be a problematic cultural practice in Ghana. Another common burial practice in Ghana is for grieving family and friends to walk in a line past the deceased body. During this process, mourners often attempt to show their grief by lying on the dead body or wiping away "tears" from the eyes of the dead body. Among communities in southern Ghana, a widow reportedly is made to drink the water used to rinse her dead husband's body to demonstrate that she was not responsible for her husband's demise (Adongo et al., 2016). Muslims in Ghana generally believed that the only way to change high-risk funeral and burial practices was through their religious leaders who understand the teachings of the Quran and the religious doctrine (Adongo et al., 2016).

In a study of 418 health workers in Benin, Aissi (2015) found that 91% knew the early signs of EVD and 60% followed the news concerning Ebola in Africa. More than a quarter of participants (28%) did not

know the difference between EVD and Lassa fever. About two-thirds of participants (67%) knew modes of transmission for EVD, however 87% were convinced that there was no cure or treatment for EVD, including traditional African medicine.

Rumors/myths

In Sierra Leone, an anthropological study by Tengbeh et al. (2018) conducted during an Ebola vaccine trial found that a common rumor about EVD was that the vaccine for the disease was a form of "slow poison" that could give participants Ebola or another disease. Both participants of the vaccine trial and non-participants reported rumors related to blood, the discomfort of giving blood, and the fear that giving blood leaves one permanently weak.

In a study in Ghana by Gbogbo & Kyei (2017), 70% of respondents reported that the bat colony in their community had in the past followed a sick chief of one of the ethnic groups who had been admitted to the hospital. According to the myth, when the chief died at the hospital, the bats remained in the community near the hospital. Twenty-six percent of the respondents in the study considered the presence of the bats to be demonic, while 5% linked them to good luck.

Risk perception

In the Alhaji, Yatswako, & Oddoh (2018) study of bushmeat handlers in Nigeria, 68% of the hunters, 61% of the vendors, and 77% of the meat consumers reported that handling the blood or body fluids of infected wildlife was a high-risk behavior for humans. A large proportion of hunters (73%) and consumers of bushmeat (72%) also reported that eating fruits that were half eaten by bats was a high-risk activity for humans; however, 73% of vendors considered this to be a low-risk activity. Handling bushmeat during EVD outbreaks was perceived as high-risk by the majority of hunters (81%), vendors (90%), and bushmeat consumers (76%).

Barriers

In Sierra Leone, respondents in a study of EVD public health messages (Bonwitt et al., 2018) stated that in some places, villagers pressured chiefs not to enforce hunting laws imposed by the government, and no one would know who hunted or consumed wild animals. Communal hunting methods ceased or continued with precautions. The study recorded several incidents where people reported other villagers to the police for consuming wild meat, in order to exact revenge over previous unrelated issues and thereby "destroy enemies." It also found that some individuals coerced hunters and trappers to share a portion of their kill by threatening to report them and their hunting activities to authorities.

Recommendations

Carter et al. (2017) reported recommendations from household members and CHVs, some of which included: being informed about EVD and feeling supported by their communities; understanding what happens at all stages of the EVD treatment process; identifying a community liaison to support families and gather information on EVD cases in the community; increasing availability and accessibility of treatment centers; and using Ebola patients' survival and negative testing stories to build hope and promote early treatment seeking behaviors.

A study (Schwerdtle, De Clerck, & Plummer, 2017) in Liberia and Sierra Leone of Ebola survivors reported four key themes among respondents. Respondents expressed degrees of mistrust in receiving treatment for EVD and suspicion surrounding EVD-related health messages, which in some scenarios prevented people from following advice regarding disinfection practices and may have exacerbated the spread of Ebola. Respondents also described messages with risk-related information that increased their levels of fear and anxiety. Messages conflicted with their culture and way of life and overemphasized what not to do. Another common theme that Schwerdtle et al. reported was how individuals and communities found it difficult to believe messages about a highly-fatal, infectious disease that had never before been experienced in the region. Although messages that were focused on risk-related information were not perceived as beneficial by participants, they expressed that messages containing stories of recovery, treatment, and care inspired hope of survival. Ebola-related health messages were criticized for: being overly-factual, being delivered in a lecturing tone, lacking clear explanations, and containing no practical information regarding how to manage Ebola in households and in the community. Schwerdtle et al. reported that developing health messages that follow a strengths-based approach to health promotion, emphasize people's strengths and self-determination, and view communities as resilient and resourceful may improve the effectiveness of Ebola health communication campaigns as well as community engagement.

A study in Ghana found that in addition to individual-level predictors, certain community-level factors seemed to explain the differences in Ebola-related stigma across communities (Tenkorang, 2017). The results showed that communities with a high knowledge of Ebola were significantly less likely to endorse Ebola-related stigma. However, communities that were worried about providing assistance and care in the event of an outbreak were more likely to endorse stigma. Tenkorang posits that these results suggest the need for multilevel interventions to equip individuals and communities with accurate information about Ebola, while addressing myths and fear.

Lassa Fever

Table 8. Summary of results, Lassa fever

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Lassa Fever	Peer-reviewed articles (10)	Sierra Leone (4) Nigeria (6)	General public, particular rural/poor communities Handlers and eaters of rat meat	Traditional burial practices that expose individuals to blood or contaminated water Handling/ consuming rat meat Eating food that has been dried on the floor (contaminated)	Health communication (education)	Lack of knowledge and misconceptions Lack of education/ awareness in local languages Rat meat is easily accessible

Lassa fever is a hemorrhagic viral fever with a rodent host, *Mastomys natalensis*, and is endemic in parts of West Africa. There have been repeated outbreaks of Lassa fever in Sierra Leone, Nigeria, and Liberia (Bonwitt J., 2016). Primary transmission of Lassa fever to humans occurs through direct or indirect contact with rodent body fluids such as urine, feces, saliva, or blood. Secondary human-to-human transmission occurs through contact with bodily fluids, or objects in the household or in health care facilities that have been contaminated (Dzingirai et al., 2017). Human-to-human transmission can also take place through aerosol secretions in the form of sneezing, sputum, stool, urine, blood, and seminal fluid (Inegbenebor, 2010). There is no vaccine and prevention is recommended through improved hygiene practices, including food storage, rodent proofing, and infection control practices (Bonwitt J., 2016)

Fichet-Calvet & Rogers (2009) reported that Lassa fever virus (LFV) is endemic in the Mano River region of Sierra Leone and the *Mastomys natalensis* rodent, host of the LFV, lives in houses and surrounding fields and forests of this area. The authors found that the humidity, rainfall, and associated movements of the rodent population encourage the stability and transmission of LFV among infected rodents in Sierra Leone. For instance, the behavioral patterns of the rodents to aggregate in houses during the dry season and disperse into the surrounding fields in the rainy season to forage for food in cultivated areas before harvesting time, are noted to influence the seasonal variability of the LFV infection.

Knowledge, attitudes, and practices

A mixed-methods study conducted in Sierra Leone by Bonwitt et al. (2016) found that the consumption of rodents is widespread with various reasons, such as taste preference, food security, and opportunistic behaviors. The study found that most respondents had heard of Lassa fever and were aware that it is a serious and fatal disease. They were familiar with the symptoms and special burial practices required. Less than half (38%) of the respondents associated Lassa fever with animals, and no one was aware of the exact carrier of Lassa fever, but frequently mentioned that shrews could transmit Lassa fever. Shrews are often perceived as “different from other rats” due to their behavior, diet, and appearance. Both qualitative and quantitative surveys showed that rat hunting is very common. The quantitative Bonwitt et al. survey indicated that more than two-thirds (69%) of rat hunters handled live rats during their hunting experiences, and around one-third reported having been in contact with urine (32.2%) or having been bitten (28%).

Bonwitt et al. (2016) also reported that during direct observations of preparing rats for consumption, no basic hygiene measures, such as handwashing, were observed. Rats are singed over fire to remove the hair and sometimes butchered. The kidneys, liver, and heart are often kept, and the rats are then smoked, grilled, and/or stewed. The rat meat is eaten alone or added to dishes. The reason for consuming rat meat was due to the belief that it provides supplementary value as a “very important source of protein.” Respondents stated that it is necessary for maintaining a balanced diet; however, most respondents also said that if rat meat were not available anymore, they would not go hungry. It was considered wasteful to throw away bush rats that were killed for pest control, and rat meat was free and easy and fast to catch in comparison to other sources of protein. Respondents expressed discomfort at discussing the topic of rat consumption and explained that they were afraid to

acknowledge the practice because they had been advised against rat consumption through messages from health care workers and on the radio.

Dzingirai et al. (2017) conducted a study of Lassa fever in rural and peri-urban communities in the forest zone of Eastern Region in Sierra Leone. This region has the highest reported incidence of Lassa fever in the world. While there was knowledge that rodents cause Lassa fever, there was common misconception about which rodent carried the virus. Tuile, a type of shrew, is avoided by the population and thought to be the Lassa rat, but *Mastomys natalensis*, the rodent that actually carries the Lassa fever is not avoided. There is no perceived risk associated with *Mastomys natalensis*, and no special caution aside from normal pest control. The study found that rodents are hunted by young boys in rural areas and are occasionally cooked as part of sacrificial ceremonies. Eating rodents is associated with poverty and is stigmatized. Exposure to Lassa fever is also related to farming patterns because *M. natalensis* is a burrowing rodent and prefers mounds constructed in fields. Dzingirai et al. found that as a result, those working in mounded fields and gardens (primarily women) are most likely to be exposed to Lassa fever.

Another study (Tobin, Asogun, Happi, Ogbaini, & Gunther, 2014) assessed knowledge and practices around Lassa fever in endemic communities of Edo State, Nigeria. More than three-quarters (76.6%) of respondents had poor knowledge of Lassa fever, and 45.8% had high risk of rodent contact. Overall, 33.7% were at risk of Lassa fever due to poor hygiene practices.

Asogun et al. (2010) published a study about knowledge and practices around Lassa fever in Nigeria that revealed that 36% of the 147 study participants had heard of Lassa fever, half of whom identified rats as the main source of infection. However, many respondents still engaged in practices that favor the transmission of Lassa fever. For example, 72% did not attempt to control rats in their homes and 43% encouraged bush-burning, during which fleeing rats are caught for food.

To assess public awareness of Lassa fever, Oladeinde, Omoregie, & Odia (2015) completed a study in three rural communities in Edo State, Nigeria and found a very low level of correct knowledge and many misconceptions among the surveyed population. Only 7.4% of participants reported having heard of Lassa fever. Among those who had heard of Lassa fever, the following modes of transmission of Lassa fever were mentioned: mosquito bites (32.15%), dog bites (25%), and eating rat-contaminated food (7%). Respondents reported that Lassa fever could be prevented by sleeping under bed nets (17.8%) or using herbal remedies (17.8%). Among those aware of Lassa fever, more than half were not aware of any mode of transmission (53.4%), as well as any way to prevent the virus (57.1%).

Inegbenebor, Ikosum, and Inegbenebor (2010) conducted a prospective study to compare case fatality rates of Lassa fever to determine community habits in Edo Central District of Nigeria. Several practices that may have caused the Lassa fever in the study were identified: consumption of rat meat as a source of protein, food contaminated by rat feces and urine, exposure to infected blood during traditional autopsies, ingestion of contaminated water during traditional burial practices, or contamination of food during corrupt food production practices.

A cross-sectional study by Olowookere, et al. (2017) in Ile-Ife, Nigeria on knowledge, attitudes, and practices around Lassa fever control and prevention showed that 41% of respondents had not heard of Lassa fever, and more than half (72.7%) were not aware that it was caused by a virus. Sixty-four percent thought that Lassa fever cannot be prevented, and nearly one-third (29.8%) responded that Lassa fever is not transmissible. Most respondents (91%) were aware that rats transmit Lassa fever, however 12% responded that humans can transmit it, and 5.4% responded that mosquitoes can transmit it. Only 28% of respondents agreed that consumption of bush rats can cause Lassa fever, and 27.5% agreed that a suspected case of Lassa fever should be reported to a nearby health center. More than half (56.5%) reported that they eat rat meat and 13.5% reported that they eat food that had been dried on a bare floor.

Recommendations

A study by Kelly (2013) shows that in Kenema District of post-war Sierra Leone, interventions to control Lassa fever and other rodent-borne diseases typically included education and awareness-raising campaigns to improve "village hygiene." This involved elimination of unprotected garbage and food storage, clearing of vegetation surrounding houses, and plugging holes that could allow rodent entry. The considerable efforts to counter Lassa fever in Kenema District also included enhancing laboratory diagnostic capacity and creating outreach teams and zoology teams that perform follow-up investigations and work once a case of Lassa fever has been confirmed. Despite these efforts, reported cases of Lassa fever have continued to increase in Sierra Leone, pointing to the biggest underlying risk factor of Lassa fever: poor quality housing. Kelly concluded that any long-term intervention to address Lassa fever in Kenema District should address poor quality housing, which is at the root of the increasing cases.

A study on knowledge and practices of Lassa fever in Nigeria by Asogun et al. (2010) conducted in 2010 recommended that government and NGO organizations in Nigeria should intensify efforts to correctly educate the population through campaigns, in particular through mass media and religious groups, on the mode of transmission and signs and symptoms of the disease. Authors of another study conducted in Nigeria to assess public awareness of Lassa fever in rural communities recommended an urgent need to increase intervention efforts by educating rural community members on causes, mode of transmission and prevention of Lassa fever, with the emphasis of using local dialects to facilitate understanding (Oladeinde et al., 2015). Authors of a cross-sectional study in Ile-Ife, Nigeria suggested that community-based education will increase community knowledge, especially among disadvantaged populations (Olowookere et al., 2017). Additionally, Olowookere et al. recommended that environmental sanitation laws be strengthened along with government and NGO approaches to control and prevent the spread of Lassa fever.

Because Lassa fever is transmitted to humans through contamination by rodent hosts or human-to-human modes, Tambo et al. (2018) suggest a "One Health" animal-human-environment approach to address Lassa fever in Nigeria. The authors propose that since there is no preventive medication or vaccine against Lassa fever, increased community awareness and health education on avoiding contact

with rodent hosts, prevention of food contamination, and food safety practices are necessary. Improved education and access to sexual and reproductive preventive measures is also important as there have been cases of Lassa virus transmitted through sex.

Marburg Virus

Marburg virus (MARV) is a viral hemorrhagic fever caused by the *Marburg marburgvirus* species. A study by Changula, Kajihara, Mweene, & Takada (2014) provides the following information on MARV. It was found that Egyptian fruit bats are the most likely natural reservoir host for Marburg virus and outbreaks of MARV have been associated with entering working or decommissioned mines or caves where the bats can be found. The MARV infections in Egyptian fruit bats have been found seasonally, with bi-annual peaks that correspond to MARV infections identified in humans.

Arboviruses

Arboviruses are viruses that are transmitted by arthropod vectors like mosquitoes, ticks, and sandflies. Transmission to humans occurs when the vector feeds on the blood of humans. Person-to-person transmission, through blood or other bodily fluids, is less common, but possible in some cases. Arboviruses include African swine fever, dengue, Japanese encephalitis, Rift Valley fever, tick-borne encephalitis, West Nile encephalitis, yellow fever, Zika, and chikungunya. However, there is little to no literature on the knowledge, attitudes, and practices regarding the majority of these arboviruses in West Africa. The only arboviruses for which the literature review uncovered relevant literature are yellow fever, Rift Valley fever, and Zika. One study argued that the reason dengue has not received the attention it deserves is because it is often misdiagnosed as malaria (Stoler, Dashti, Anto, Fobil, & Awandare, 2014).

Yellow Fever

Table 9. Summary of results, yellow fever

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Yellow Fever (Arbovirus)	Peer-reviewed articles (3)	Côte d'Ivoire (2) Nigeria (1)	General public	Not vaccinated for yellow fever Standing water that creates breeding sites for mosquitoes	Mass vaccination Vector control Bite protection	

Yellow fever is estimated to cause up to 30,000 deaths each year in Africa alone (Fatiregun, Sangowawa, & Abubakar, 2010). It is preventable by an effective and affordable one-time vaccine that is routinely administered in most endemic countries to children at 9 months of age. However, there is no specific antiviral drug to treat yellow fever.

The literature search uncovered three marginally relevant articles. In Nigeria, a pretraining test of disease surveillance and notification officers found very low knowledge of yellow fever surveillance requirements (Fatiregun et al., 2010). A study following a 2008 yellow fever epidemic in Abidjan, Côte d'Ivoire, found that high population density and high density of mosquito larva (particularly in water storage containers) may have been responsible for the outbreak (Kone et al., 2013). Another study from Côte d'Ivoire found that people over the age of 15 years were at higher risk because many had not been vaccinated (Attoh-Touré, Dagnan, & Tagliante-Saracino 2010).

Rift Valley Fever

Table 10. Summary of results, Rift Valley Fever (Arbovirus)

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Rift Valley Fever (Arbovirus)	Peer-reviewed articles (1)	Mauritania (1)	General public Livestock keepers Meat processors Meat consumers Veterinarians	Environmental: dry spell of 6 days followed by intense rain Proximity to livestock	Vector control Bite protection Boil milk products Cook meat thoroughly Precautions when handling sick animals and carcasses	

Rift Valley fever is transmitted from animals (primarily livestock) to humans through contact with blood, body fluids, or tissues of an infected animal and through mosquitoes (Boushab, Savadogo, Sow, & Soufiane, 2015). A qualitative study of Rift Valley fever in Mauritania identified eating raw or undercooked meat and drinking unpasteurized milk as risk factors (Boushab et al., 2015). Another study identified bodies of water within one kilometer of where the herd overnights (within the 'active flight' distance for mosquitoes that primarily feed at night and transmit Rift Valley fever) as a risk factor (Kanouté et al., 2017). At least one study suggests that six days of dry weather followed by heavy seasonal rainfall can be linked to outbreaks of Rift Valley fever, and early warning systems have been developed using satellite imaging to detect the presence of ponds (Vignolles et al., 2009).

Zika

Table 11. Summary of results, Zika (Arbovirus)

DISEASE	SOURCES	COUNTRIES	POPULATIONS	RISK FACTORS	INTERVENTIONS	BARRIERS
Zika (Arbovirus)	Peer-reviewed articles (1)	Nigeria (1)	General public Pregnant women		Vector control Bite protection	

The Zika virus is transmitted primarily by mosquito (particularly *Aedes aegypti*), but it also can be transmitted person-to-person through sexual intercourse and pregnancy. Zika has been associated with microcephaly and Guillain-Barré syndrome in newborns. A study of Zika knowledge among 200 health care workers in Nigeria found that most (64%) had poor knowledge of the Zika infection including symptoms, testing, and treatment (Akunne, Chukwueke, & Anosike, 2018). The same study showed that knowledge was somewhat better on modes of transmission and risks to pregnant women and the unborn fetus.

Priority Zoonotic Diseases in Sierra Leone

The first One Health Zoonotic Disease Prioritization Workshop conducted in 2017 in Sierra Leone identified viral hemorrhagic fevers, rabies, avian influenza, *Salmonella*, anthrax, and plague as endemic and emerging zoonotic diseases of most significant concern in Sierra Leone (USAID, 2017). There is an abundance of information from Sierra Leone on behaviors, perceptions, and attitudes related to Ebola virus disease. However, there is very little information in the published literature about community-level perceptions and practices, and the sociocultural norms that influence transmission of many of the other priority zoonotic diseases (PZDs) in Sierra Leone.

The following sections represent a summary of the published research on zoonoses in Sierra Leone, with a focus on PZD identified during the One Health disease prioritization exercise. Relevant information from unpublished grey literature and local program documents are also included when available.

Other Priority Zoonotic Diseases

No published literature was found on the sociocultural norms, behaviors, and individual- or community-level perceptions related to the viral hemorrhagic fevers—yellow fever, dengue fever and Rift Valley fever, avian influenza, *Salmonella*, anthrax, or plague in the Sierra Leone context.

Disease Surveillance and Reporting

Published information about disease surveillance in Sierra Leone is limited. Assessments conducted in several countries in West Africa including Sierra Leone following the EVD outbreak highlighted the fact that community-level surveillance, preparedness, and response structure was lacking (Govindaraj & Herbst). A toll-free 117 alert system was established in Sierra Leone during the EVD outbreak to facilitate rapid reporting and investigation of Ebola cases and deaths. There are suggestions that adapting and encouraging community-based reporting strategies such as the 117 phone alert system could contribute to the rapid detection of public health threats and controlling emerging or re-emerging epidemics (Alpren et al., 2017).

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