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One Health Approaches in Zoonotic Disease Control

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ABSTRACT

Zoonotic diseases constitute a major global health challenge, accounting for the majority of emerging and re-emerging infectious threats and disproportionately affecting low and middle-income countries. The One Health approach offers an integrative framework to address the complex linkages between human, animal, and environmental health that drive zoonotic transmission. This narrative review examines the conceptual foundations, epidemiological rationale, governance frameworks, surveillance systems, and intersectoral collaborations underpinning One Health approaches in zoonotic disease control. Drawing on diverse case studies, including avian influenza, Ebola, and Nipah virus, the review highlights the centrality of coordinated human and animal environmental interventions for effective disease prevention, preparedness, and response. Ethical considerations, equity concerns, and community engagement emerge as critical determinants shaping One Health implementation, especially in resource-constrained settings. Despite increasing global advocacy, significant governance gaps, fragmented data systems, insufficient investment, and limited modelling capacity hinder operationalization. Strengthening multisectoral governance, expanding surveillance integration, advancing interdisciplinary research, and prioritizing community-led strategies are essential to realizing the transformative potential of One Health in mitigating current and future zoonotic threats.

Keywords: One Health, Zoonotic Diseases, Surveillance Systems, Intersectoral Collaboration, and Spillover Transmission.

INTRODUCTION

Emerging and re-emerging infectious diseases disproportionately affect marginalized populations in low- and middle-income countries, exert unwarranted social and economic impacts, and impede global developmental progress. Most of these diseases are zoonoses, which account for 75% of human infectious agents and, therefore, pose particularly significant threats [1-6]. The One Health concept provides an integrated response to the challenges posed by such zoonotic diseases, which have complex aetiologies and diverse zoonotic reservoirs, by promoting sectoral actions in human, animal, and environmental health [7-10]. The human health sector possesses substantial datasets, analytical experience, and modelling tools that are relevant to understanding and intervening against zoonoses, but these remain underutilized [11-16]. One Health emerged in recognition that the health of humans, animals, and ecosystems is interconnected. Pathogen spillover from wild reservoirs to humans has been implicated in over two-thirds of documented epidemics, as demonstrated by COVID-19[17-20]. The wildlife "supply chain, comprising animal husbandry, wildlife exploitation, habitat destruction, and urbanization, fuels pathogen outbreaks [21-24]. Consequently, human health strategies must extend beyond the human sphere to encompass environmental modifications and animal populations. Global commitments such as the Strategic Framework for Collaboration on One Health between WHO, OIE, and FAO encourage the establishment of One Health frameworks to combat endemic zoonoses and mitigate the emergence of novel diseases [25-30].

Conceptual Foundations of One Health

The One Health concept provides a framework that strengthens collaboration between human, animal, and environmental health [31-35]. The term originated in the 2000s, yet the complementary interdependencies of these disciplines have been studied for centuries [36]. Systematizing endemic and emergent disease research in a singular paradigm addresses the complexity of health determinants of multiple domains, counteracts harmful

compartmentalization, and applies diverse disciplinary tools [37-40]. Among the One Health applications, zoonotic disease control serves as a prime example that exemplifies the conceptual foundations of the approach. Of the approximately 1,407 described human pathogens, 61% are zoonotic in origin; furthermore, 75% of new emerging infectious agents identified in the past two decades are of animal origin [41-43]. The rubric also lends itself to studying other One Health diseases, and the cases of bush meat and antimicrobial resistance provide insights into One Health implementation for broader health concerns [44-46]. Zoonotic diseases constitute a high-priority One Health issue since the transmission of many endemic and emergent pathogens occurs through intimate links between species. Livestock and companion animals maintain vital economic, social, and companion bonds with humans. The emergence of bushmeat as a primary food source in urban centers often derives from the biological connection to hunting [47-50]. The epidemiological and socioeconomic attributes associated with zoonotic diseases validate the selection of this topic for a One Health analysis [51-54]. The epidemic potential of zoonotic diseases often relies upon the dynamic of interhuman transmission after an initial human spillover, yet environmental and animal health variables play integral roles in determining the risk posed by an outbreak-event. In particular, most emerging zoonoses rely not only on identification of animal hosts but also on elucidation of transmission pathways and inter-human spread mechanisms [55]. A One Health methodology encourages the coupling of intersectoral data sources to construct integrated models that illuminate the broader determinants controlling pathogen emergence, thereby assisting in the evaluation of alternative intervention strategies [56-60].

Epidemiological Rationale for One Health in Zoonoses

The epidemiological underpinnings for One Health are framed around pathogen circulation and spillover. Zoonotic transmission by mammals typically involves host reservoirs that cycle pathogens at animal and animal interfaces, allowing infrequent spillover to human hosts [61]. For example, HIV-1 emerged from Simian Immunodeficiency Virus (SIV) through reservoirs comprising multiple primate species in Central Africa [62]. Intersectoral collaboration enhances understanding of pathogen emergence; thus, investigation of animal reservoirs has become integral to the epidemiology, biology, and control of various emerging infectious diseases. Determining reservoir species and risk factors complicates efforts to contain diseases such as SARS-CoV, West Nile Virus, and Nipah virus [63]. Fungal pathogens, including Candida auris, have also emerged through transboundary routes and environmental reservoirs, underlining the need for a multidisciplinary approach. The range of spread contributes to the understanding of environmental effects on emergence [64-69]. Analyses of spillover reveal the importance of intermediary species, which facilitate the human transmission of Ebola virus, Marburg virus, and Spongy Encephalopathy and Argentinean Hemorrhagic Fever [11]. Other high-consequence pathogens, such as monkeypox and avian influenza, circulate among diverse wildlife yet require additional understanding of the viral circulation cycle within wildlife before transmission to humans occurs [12]. Several One Health approaches have been developed to analyze pathogen circulation, particularly in Africa. Human and animal environment systems, such as those in the ecohealth community, extend the concept to encompass broader environmental interactions and collective animal and plant health [8]. Intersectoral data integration supporting One Health spans various transmission pathways, including water-borne transmission of Rabies Virus, water-smuggling Leptospira spp., and ecologically dispersive Hantavirus; addressing them separately impedes risk evaluation of these strategic interventions [14]. Considered analysis of multiple data sources and partnership platforms sustains modelling, supports prioritization of One Health actions, and improves understanding of pathways and their management [3].

Frameworks and Governance for One Health

One Health approaches can apply to various zoonotic diseases, provided the nature of the human-animal-environment interfaces warrants the investment of additional resources [12]. The epidemiology and surveillance data for each disease can help judge when, where, and how to implement One Health activities [11]. The approach follows the overall risk and disease-based model used in other sectors, enabling countries to tailor the approach to local needs and to widen the application of One Health concepts in disease control, ultimately improving national capacity to address multi-sectoral risks and events [5]. Analysis of public health events over the past two decades indicates that One Health is relevant to many zoonotic and vector-borne diseases [6].

Surveillance Systems and Data Integration

As the world's interface with nature changes, new disease threats to health and biodiversity are on the rise. Development, climate change, and associated global change drivers such as landuse change, animal trade, wildlife harvesting, increased demographics, and biomass sourcing are reshaping the eco-evolutionary dynamics of pathogens, pathogens' natural hosts, and the pathogens' interlinks with their reservoir(s) [8]. These changes drive formerly weak links between species into robust pathways of cross-species transfers [7]. One Health approaches to disease prevention and surveillance are therefore on the rise. Avian influenza is an important zoonotic disease in Thailand. Enhancing Thailand's One Health avian influenza (AI) surveillance system will require an integrated surveillance reporting system and improved intersectoral laboratory collaboration at national and subnational

levels. Maintaining situational awareness of AI across diverse wildlife, domestic, and food-chain compartments is critical [8]. An integrated surveillance reporting system is therefore feasible and necessary to preserve and enhance Thailand's robustness in AI surveillance, given the many ongoing One Health initiatives across priority zoonoses [11]. A unified data management system enables aggregation of local-scientist reports of AI cases originating from wildlife, domestic, veterinary, and food-chain sectors into a national shared-space platform. Intersectoral collaboration amplifies the impact of local-scientist contributions on national AI monitoring and enhances resilience to changing surveillance risks [10].

Collaboration across Sectors: Human, Animal, and Environmental Health

One Health recognizes the close relationship between human, domestic animal, and wildlife health and the health of the ecosystem [3]. It promotes an integrative and multisectoral public health approach and aims to optimize human and animal environment interactions and promote health, welfare, and sustainability of all three systems. The current paradigm of growth and development impedes the achievement of the goals enshrined in One Health [8]. For example, human health and the health of domestic animals and wildlife have become increasingly separated through urbanization, socioeconomic development, and globalization, leading to the emergence of many infectious diseases of public concern [9]. The One Health approach recognizes that the control of zoonoses is best achieved by collaboration between public health, veterinary, and environmental sectors [14]. Despite common understandings about the need for inter-sectoral collaboration, effective partnerships remain limited in many parts of the world. Zoonosis control requires an understanding not only of the factors associated with human health but also of those that influence animal health, antimicrobial resistance, food safety, biodiversity, and conservation [10].

Risk Assessment and Intervention Strategies

In a One Health framework, estimating the risk associated with the introduction and spread of a zoonotic disease involves hazard identification, exposure assessment, vulnerability assessment, and the evaluation of possible interventions [11]. A comprehensive risk assessment consists not only of these four components, but also of the prioritization of the most important risk elements [10]. The process can be enhanced through linkages to economic analysis, which enables the projection of economic, social, and other consequences associated with the various hazards, exposures, and interventions identified [11]. Mathematical or statistical models are often utilized to project the likely outcomes associated with different hazards, exposures, and interventions. These projections support decision-making processes and the planning of information-gathering strategies that aim to reduce the uncertainty surrounding the magnitude and importance of various possible zoonotic disease events and their control measures [13]. They also serve as a guide for identifying which hazards should be the highest priority for risk assessment, and which elements of risk management warrant the most detailed consideration. These models can also be used to evaluate the economic efficiency of alternative approaches for mitigating zoonotic disease events to determine potential investments that could facilitate a more complete risk management assessment of zoonoses affecting society [10].

Case Studies: Zoonotic Diseases and One Health Applications

Recurring outbreaks of emerging and re-emerging zoonoses such as Ebola virus, avian influenza, and Nipah virus underscore the interconnectedness of human, animal, and environmental health [1]. Control of zoonotic disease must, therefore, encompass the integration of the human, animal, and environmental health sectors at local, national, and transnational levels 4. Consequently, a collaborative, interdisciplinary, One Health approach has been promoted as a means of addressing complex health challenges [2]. Zoonotic disease threats have triggered coordinated global action, including the launch of the PREDICT project in 2009. The project has generated knowledge, tools, and practices for implementing One Health at small and large scales, often capitalizing on existing institutional structures, information, and networks [8]. PREDICT's experience in addressing emerging zoonotic diseases highlights that One Health remains aspirational, its intricacies often poorly understood, and its implementation challenging[9]. Nevertheless, opportunities to advance One Health exist, particularly through case studies of zoonotic diseases that demonstrate its relevance and utility a1912ac1c-7f5d-41cd-9963-bb207a8522d2 different contexts.

Ethics, Equity, and Community Engagement

The ethics underpinning One Health continually provoke discussion, spanning engagement, intellectual property, and risk assessment [8]. Zoonotic diseases impact diverse communities and economically vulnerable groups. Complex ethical considerations arise in initiating collaborations, necessitating thorough exploration and explicit tracking of critical dimensions [6]. Emerging risks related to climate change, globalization, human population growth, and sociopolitical factors amplify urgent concerns about emerging infectious diseases [4]. Centuries ago, the Zoonotic Diseases Action Plan highlighted disparities in health, access, and risk management between communities and nations, addressing zoonoses and One Health initiatives. The Paris Agreement underscored the need for treating disadvantaged, marginalized, and underrepresented groups fairly [8]. Continued fundamental

inequities profile ethics as core to global efforts across the public, private, and civil society sectors 12. Communities must voluntarily, explicitly, and freely engage in broader projects under culturally relevant conditions [8]. Underdeveloped conditions with unclear consent assume undue risks. A lack of control over local resources generates vulnerability to multi-national enterprises set to exploit local contexts, often without explicit consent or recognition of variation beyond the pilot stage [9]. Community-level dynamics hinge on trust. One Health dominates mobilization funding amid resource-poor settings, triggering fragile relations entailing participation in the overall edifice whilst retaining autonomy and security [13]. Zoonosis proponents representing local interests and the poor proactively engage with institutions generating One Health resources, outreach, and education at multiple levels. Local champions and trustworthy brokers foster responsiveness to expressed needs, shaped by lived experience [14]. Implementation hinges on species selection, funding allocation, submission venues, community engagement, and ultimate participation in operational delivery. One Health elevates species and targeted priorities amid anxiety about loss of control, over-generalization, misinterpretation, and lack of appreciation for particularities [13]. Participating groups perceive alternative frameworks as monopolizing or commandeering while encountering practical constraints, limited human and veterinary resources, institutions, skills, and financing. Unpacking of complex professional, organizational, and institutional contexts should feed back into overall One Health initiatives [12].

Challenges, Limitations, and Future Directions

Addressing the challenges that One Health approaches to zoonotic disease face is necessary to identify future research and policy needs. A major obstacle to progress is that significant governance gaps at both international and national levels prevent coordinated, multisectoral collaboration on a range of health and environmental issues [14]. Among the most critical are climate change, food security, and pollution [11]. Authority to implement One Health initiatives is often hampered further by a lack of a formal mandate to work on zoonoses or the inability of multisectoral commissions to influence action outside their own specific focus area [5]. Resources for implementing One Health at the human and animal environment interface remain insufficient in many countries, especially for basic needs such as addressing airborne contaminants and collecting climate data [12]. Emerging diseases continue to proliferate, aggravating an already burdensome global disease load. Data necessary for risk assessment often remain fragmented among various institutions, agencies, and sectors [13]. Despite extensive messaging promoting One Health, political commitment to build data infrastructure, and investment in activities such as modeling that support integrated assessment, little actual progress has been made. Such modeling would permit systematic evaluation of the interactions among animal, human, and ecosystem health, yet few estimates of the global burden attributable to zoonotic and vector-borne pathogens have been attempted [13]. In areas where understanding of the interaction between climatic, demographic, land use, and other drivers of zoonoses is more developed, models yield useful projections under plausible socioeconomic and climate scenarios [14]. Beyond the health sector, there has been little information generated on the future evolution of animal and ecosystem health or on the interactions among various sectors. Efforts aimed at determining requirements for One Health study and developing a description of the scientific, institutional, and policy-linked questions constituting the next generation of One Health research remain largely incomplete [15-22].

CONCLUSION

Zoonotic diseases remain among the most significant public health threats of the twenty-first century, driven by intensifying interactions between humans, animals, and the environment. The One Health approach presents a vital paradigm for understanding and managing these complex dynamics by integrating expertise, datasets, and interventions across sectors. This review underscores that while the conceptual foundations of One Health are well established, its practical implementation continues to face substantial challenges, including fragmented governance, inadequate funding, and persistent inequities in data access and decision-making power. Case studies demonstrate that One Health initiatives can significantly enhance disease surveillance, risk assessment, and outbreak response when supported by strong institutional coordination and community engagement. Moving forward, realizing the promise of One Health requires sustained political commitment, expansion of integrated surveillance platforms, strengthened interdisciplinary modelling capacity, and ethical frameworks that prioritize equity and local ownership. By bridging the gaps between human, animal, and environmental health, One Health can serve as a cornerstone for global strategies to reduce zoonotic disease burdens, build resilient health systems, and protect vulnerable populations in a rapidly changing world.

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