



Review

Overview of Singapore's One Health Strategy

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Simple Summary: Singapore is a densely populated city-state with unique challenges related to human, animal, and environmental health. To address these interconnected issues, Singapore has adopted a One Health strategy, which brings together efforts from various sectors to tackle problems like emerging or zoonotic infectious diseases and the growing resistance of bacteria to antibiotics. This paper reviews Singapore's efforts, highlighting its strengths, such as advanced disease monitoring systems, coordinated actions across government agencies, and public health initiatives. However, it also identifies areas for improvement, including better partnerships with private healthcare providers, more efficient sharing of health data, and increased public awareness of the links between human, animal, and environmental health.

Abstract: The One Health approach integrates human, animal, and environmental health to address complex challenges like emerging zoonotic diseases and antimicrobial resistance (AMR). Singapore's dense urban environment, biodiversity, and role as a global hub make it vulnerable to these health threats, necessitating a robust and coordinated One Health framework. This paper reviews Singapore's One Health strategy, focusing on governance, surveillance, cross-sector partnerships, and public health infrastructure. A structured literature review, including peer-reviewed articles and grey literature, identified key strengths and gaps. Strengths include interagency coordination through the One Health Coordinating Committee, advanced surveillance systems like CDLENS and SIDPIC, and key institutions such as the National Centre for Infectious Diseases (NCID) and the National Public Health Laboratory (NPHL). However, gaps remain in multi-sector engagement, data-sharing mechanisms, and public awareness of One Health principles. To address these challenges, this paper recommends enhancing multi-sector collaboration, strengthening data-sharing networks, and increasing public education on One Health. Investments in preventive medicine, cross-border capacity-building, and leveraging artificial intelligence for predictive analytics are essential for bolstering Singapore's health security. By addressing these gaps, Singapore can enhance its preparedness and serve as a global leader in One Health implementation.



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1. Introduction

The One Health approach is a multidisciplinary strategy that acknowledges the interconnectedness of human, animal, and environmental health, promoting collaboration across these sectors to address health challenges effectively. With the increasing prevalence of emerging infectious diseases, particularly those of zoonotic origin, a unified response

that includes human health professionals, veterinarians, ecologists, and policymakers has become increasingly important. As population density, urbanization, and environmental change continue to grow, the relevance of a One Health framework is underscored, particularly in managing zoonotic disease transmission.

In Singapore—a densely populated, highly urbanized city-state with considerable biodiversity—the development of a robust One Health strategy is essential. Singapore’s status as a trade and travel hub in Southeast Asia presents unique vulnerabilities to regional and international health threats. These factors necessitate a coordinated response to zoonotic diseases that could spread across borders.

This paper provides a comprehensive review of Singapore’s One Health strategy, with a focus on assessing the country’s overall One Health Strategy. To date, no comprehensive review of Singapore’s One Health framework has been conducted. This review, therefore, aims to synthesize existing efforts, outline key strategies, and suggest recommendations for the nation to increase preparedness for health threats of zoonotic origin.

One Health Challenges in Singapore

Singapore faces several notable challenges related to One Health and zoonotic diseases due to its dense population, urban environment, tropical climate, and high levels of human–animal–environment interaction. Major challenges include:

Dengue. Dengue is endemic in Singapore and remains a major public health challenge [1]. The country’s tropical climate and urban landscape provide ideal breeding grounds for *Aedes* mosquitoes, the primary vectors. Managing dengue requires coordinated efforts in vector control, public education, and rapid outbreak response.

Avian Influenza. Although Singapore has not experienced large-scale avian influenza outbreaks, its position as a global travel and trade hub, along with its position along the pathway of migratory birds, increases the risk of avian influenza introduction [2].

Foodborne Pathogens. Singapore is consistently at risk of enteric diseases caused by bacteria like *Salmonella* and *Campylobacter* infections, which can spread through contaminated food consumption. This is highly relevant to Singapore since it relies heavily on imported food and large-scale food distribution systems [3].

Antimicrobial Resistance (AMR). AMR is a growing concern in Singapore [4], as in many densely populated regions. The overuse of antibiotics in healthcare- and animal-related industries contributes to the spread of resistant bacteria, making it harder to treat infections in both humans and animals.

Imported Zoonotic Disease Risk. Singapore, like any travel hub, will see high volumes of food or animal imports, as well as the movement of live animals across borders. This increases the risk of importation of zoonotic diseases that are not presently endemic in Singapore [5].

Emerging Zoonotic diseases. As a highly connected global hub, Singapore is at risk of importing emerging zoonotic viruses arising elsewhere in the world [5,6]. The COVID-19 pandemic and the SARS pandemic were perfect examples of this risk. Furthermore, there is a theoretical risk of zoonotic diseases emerging in Singapore given the nature of population density.

Wildlife and Urban Interface. As Singapore continues to develop, increased urbanization and encroachment on natural habitats bring wildlife into closer contact with human populations, increasing the risk of zoonotic disease transmission [7].

2. Methods

A structured literature review was conducted to evaluate the existing One Health strategies in Singapore, with a focus on the interconnected domains of human, animal,

and environmental health. This review utilized publicly available information to ensure comprehensive and transparent access to relevant sources. The search strategy was designed to capture a broad range of literature across multiple databases, specifically targeting publications that explored One Health concepts within the contexts of veterinary, animal, human, and environmental health in Singapore.

Regarding the published literature search, the initial search terms included “One Health” AND (“Veterinary” OR “Animal”) AND (“Medicine” OR “Human”) AND (“Environment” OR “Ecosystem”) AND “Singapore”. This search was applied across three major databases: PubMed, Embase, and Cochrane Library, yielding 181 results.

After removing duplicates, the articles retrieved were first screened by title, resulting in the selection of 14 papers. These were further refined by abstract review, with 6 articles ultimately meeting the inclusion criteria for in-depth analysis. Inclusion criteria were based on relevance to One Health frameworks, specifically studies that highlighted cross-sectoral collaboration or interventions involving human, animal, and environmental health within Singapore.

In addition to peer-reviewed academic articles, a targeted search for grey literature was conducted. Unlike the published literature search, which used predefined search terms, the grey literature search adopted a more flexible and contextual approach. Relevant reports, policy documents, case studies, and non-peer-reviewed materials were identified by reviewing key governmental and organizational websites, such as those of the Ministry of Health (MOH), National Environment Agency (NEA), Singapore Food Agency (SFA), and National Parks Board (NParks). This approach was chosen to ensure that critical supplementary insights, often not indexed in academic databases, were included to provide a comprehensive evaluation of Singapore’s One Health strategy. Specifically, publications from government agencies like the MOH and NEA provided critical insights into governmental initiatives, legislative frameworks, and local partnerships that support One Health efforts in Singapore. This grey literature added essential context to the findings, helping to build a more comprehensive understanding of Singapore’s One Health strategy and its current implementation.

Data from each source were extracted and categorized based on the primary focus areas: governance, infrastructure, cross-sector partnerships, surveillance capabilities, and strategic moves in relation to One Health. Key findings were synthesized to assess the strengths and gaps of Singapore’s One Health strategy.

3. Results

3.1. Current Infrastructure and Systems

Singapore has established a range of infrastructure and systems dedicated to implementing One Health principles, particularly in areas of zoonotic disease prevention and control, AMR management, and cross-sectoral collaboration. Key components of Singapore’s One Health infrastructure are outlined below.

3.1.1. Government Agencies

Government agencies in Singapore play a pivotal role in coordinating One Health initiatives across the human, animal, and environmental health sectors. Established in 2012, Singapore’s national One Health Framework serves as a crucial platform for fostering collaborative, multisectoral approaches to address threats at the human–animal–environment interface [8]. Since its inception, this framework has enabled coordinated capacity-building efforts, joint actions to combat antimicrobial resistance, and the development of protocols to manage zoonotic and foodborne disease outbreaks.

Under this framework, the Ministry of Health (MOH) in Singapore collaborates closely with other key agencies, including the National Environment Agency (NEA), Singapore Food Agency (SFA), National Parks Board (NParks), and the Public Utilities Board (PUB). Each agency contributes its expertise to support integrated efforts in disease prevention, monitoring, and outbreak response. The NEA oversees environmental health and vector control efforts [9], while the SFA is responsible for food safety regulation [10]. NParks, through its Animal and Veterinary Service (AVS) division, plays a significant role in animal health and welfare, addressing zoonotic risks at the animal–environment interface [11]. The PUB, tasked with managing Singapore’s water resources, ensures the maintenance of safe and sustainable water systems, contributing to environmental health under the One Health framework [12].

Inter-agency coordination among these organizations enables a cohesive approach to zoonotic disease management, facilitating efficient information-sharing and joint initiatives for disease surveillance and response. This collaborative model enhances Singapore’s capacity to address health risks arising from the interconnectedness of human, animal, and environmental domains. The manifestation of such coordination is expressed in the creation of platforms such as the One Health Coordinating Committee, Specialized Work Groups, and the Communicable Disease Agency, which will be elaborated on later in this paper.

3.1.2. Health Facilities

Hospitals

All hospitals in Singapore contribute to the broader One Health effort, particularly in the patient-facing aspects of infectious disease management. These facilities collaborate closely with government agencies to implement standardized protocols for outbreak response, ensuring a coordinated approach across the healthcare system.

However, the National Centre for Infectious Diseases (NCID) in particular plays a leading role as the primary facility dedicated to infectious disease management in Singapore [13] and is a central element in the country’s One Health framework. As a specialized hospital for infectious diseases, NCID also functions as a hub for managing zoonotic diseases, providing treatment, conducting research, and supporting containment efforts. NCID has the capability to collaborate with other hospitals across Singapore, particularly in handling severe cases. For example, NCID houses the High-Level Isolation Unit (HLIU) [14], which is equipped to safely contain and manage high-consequence pathogens and novel infectious agents. This unit further strengthens Singapore’s preparedness and response capacity, enabling the healthcare system to handle complex infectious threats within the One Health framework.

Laboratories

Singapore’s laboratory network forms an essential part of its One Health infrastructure, with the NCID housing the National Public Health Laboratory (NPHL) [15]. Established in March 2009 by Singapore’s Ministry of Health, the NPHL plays a pivotal role in detecting zoonotic pathogens, tracking disease transmission, and responding to infectious disease outbreaks. Equipped with advanced facilities, the NPHL offers high-throughput testing, genomic sequencing, and other critical diagnostic services, supporting swift responses to emerging zoonotic diseases and comprehensive, ongoing surveillance efforts.

The NPHL has been instrumental in outbreak investigations, including those for the 2009 H1N1 pandemic, Chikungunya, and the Zika outbreak in 2016. Currently, it conducts surveillance for highly infectious pathogens such as MERS-CoV, H7N9, and Ebola. Presently integrated into the NCID, the NPHL includes a biosafety level 3 (BSL3) containment facility, dedicated to monitoring infections of public health importance and

identifying novel pathogens [15]. In addition, all laboratories of major tertiary hospitals in Singapore are equipped to test for zoonotic diseases common in the country, enhancing the national capacity to respond to infectious threats.

3.1.3. Surveillance Systems

Singapore has established a robust infectious disease surveillance system in general. These surveillance activities naturally include tracking AMR patterns, zoonotic disease monitoring, and syndromic surveillance for the early detection of potential outbreaks.

Surveillance Within Singapore

Firstly, Singapore employs passive surveillance, which relies on primary care doctors, clinics, and hospitals across Singapore to report cases of notifiable diseases to the Ministry of Health (MOH) [16]. This reporting allows the MOH to monitor the spread of diseases within the community, analyze trends, and detect outbreaks. This approach, however, depends on the accuracy and completeness of reports from these healthcare providers. This is aided by the Communicable Diseases Live & Enhanced Surveillance (CDLENS) system [17]. CDLENS was launched in Singapore on 15 July 2006 and is a centralized platform for infectious disease notification, outbreak management, and real-time information access. Linked to essential e-services on the Health Professionals Portal (HPP), CDLENS integrates tools like the National Immunization Registry and adverse event reporting, supporting Singapore's One Health strategy by enabling timely disease notifications and updates.

Next, Singapore's syndromic surveillance is especially important for the early detection of infectious disease outbreaks. For example, programs like the Acute Respiratory Infection (ARI) Surveillance Program [18] survey the population for patterns of ARI, where an explained pattern might signal an emerging or re-emerging disease in the community. On the hospital side, the Severe Illness and Death from Possibly Infectious Causes (SIDPIC) program was established in 2009 [19]. SIDPIC is a hospital-based surveillance initiative in Singapore that reviews cases of unexplained deaths and critical illnesses to identify emerging or re-emerging pathogens early. This enhances the nation's capacity to detect public health threats.

Wastewater surveillance is overseen by the NEA and is a relatively new but effective method of tracking infectious diseases in the population [20]. By analyzing wastewater for traces of pathogens (such as SARS-CoV-2), authorities can detect the presence of infectious agents in the community without relying on individual case reporting. This type of environmental surveillance can offer an early warning system for emerging or re-emerging infectious diseases and provide insights into infection trends across different areas. Wastewater surveillance serves mainly as a complement to other surveillance efforts, especially in situations where individual testing is limited or untenable or if asymptomatic cases go undetected.

Border Surveillance

In terms of border surveillance of zoonotic threats, the AVS operates a comprehensive Biosurveillance system [21] to mitigate threats. This involves pre-border activities such as engaging with overseas stakeholders and accrediting countries approved for exporting animals and animal products. Additionally, AVS conducts horizon scanning and risk assessments to identify and prepare for potential external disease threats. At the border, AVS performs animal inspections, sampling, and quarantine services to ensure imports meet Singapore's health standards, supported by diagnostic laboratory technologies at the Centre for Animal and Veterinary Sciences. Post-border, the biosurveillance effort continues through licensing, inspections, and health management programs for domestic animal and wildlife populations.

For known threats like COVID-19, Singapore employs surveillance to monitor imported cases. This approach allows authorities to track the inflow of anything of interest, such as COVID-19 variants of concern, and implement necessary border measures to prevent further spread within the country [22].

3.1.4. Academic Bodies

Academic institutions and research centers in Singapore contribute substantially to the country's One Health infrastructure. Universities (such as the National University of Singapore's Saw Swee Hock School of Public Health) and research institutes conduct studies on zoonotic diseases, antimicrobial resistance, and other relevant areas. These bodies, often supported by and working closely with government agencies, conduct both basic and applied research, offering insights that inform policy and practice. One notable example is the Programme for Research in Epidemic Preparedness and Response (PREPARE) [23], established in 2022 to strengthen Singapore's capabilities in pandemic research. PREPARE focuses on developing tools, methods, and products designed to respond effectively to future disease threats, supporting Singapore's broader One Health strategy through enhanced research and innovation in epidemic preparedness.

3.2. Key Identified Strategies and Strengths Singapore's One Health Approach

3.2.1. Interagency Cooperation and Integration

Perhaps the most important strength of Singapore's One Health strategy is the effective cooperation and integration among various government agencies, which prevents siloed work and fosters a coordinated approach to public health. Key agencies work closely to address health threats at the human–animal–environment interface. This interagency collaboration ensures that expertise from each sector is leveraged, enabling a more comprehensive response to zoonotic diseases and AMR.

Such cooperation extends to public hospitals and healthcare facilities, facilitating the rapid implementation of outbreak and preventive measures. During health crises, government agencies coordinate with hospitals to establish response protocols, support laboratory diagnostics, and ensure timely data sharing. This integrated approach was particularly evident through the scale of operations during the COVID-19 pandemic, where agencies and healthcare institutions collaborated on everything from testing protocols to public communication strategies, ensuring a cohesive national response.

3.2.2. Central Coordination

Central coordination is a key feature of Singapore's general approach to public health. This is likely due to the country's small geographical size and high population density, which make centralized oversight both feasible and effective. This centralized approach has been applied to Singapore's One Health framework as well.

One Health Coordinating Committee

The One Health Coordinating Committee (OHCC), established in 2012, exemplifies this central coordination [24]. The OHCC is a transdisciplinary, multi-agency workgroup designed to integrate One Health efforts across the human, animal, water, and environmental health sectors. By bringing together representatives from diverse fields, the OHCC enables Singapore to implement a cohesive, collaborative One Health strategy that addresses health threats at the human–animal–environment interface.

Specialized Work Groups

Specific One Health issues are also managed through central coordination. The One Health challenge that most exemplifies this is AMR. The One Health Antimicrobial Re-

sistance Work Group [25], which reports directly to the OHCC, is responsible for recommending policies and strategies to control AMR and ensuring a coordinated response among various sectors. To further strengthen AMR efforts, three technical sub-working groups have been established under the One Health AMR Work Group [26]. These sub-groups focus on cross-sectoral coordination of AMR-related education, surveillance and risk assessment, and research activities. This multi-layered coordination structure allows for a unified, strategic approach to challenges, enhancing Singapore's preparedness and response capabilities across sectors.

Dedicated Communicable Disease Statutory Board: Communicable Disease Agency

In a recent announcement by Health Minister Ong Ye Kung [27], Singapore revealed plans to establish a dedicated government statutory board, the Communicable Disease Agency (CDA). This new agency is expected to further strengthen Singapore's infectious disease control efforts. Given Singapore's awareness of the importance of One Health, CDA will likely include a One Health department, enhancing cross-sectoral collaboration in managing zoonotic and communicable disease threats. The establishment of this agency reflects Singapore's ongoing commitment to a coordinated, integrated approach to public health, particularly in addressing challenges at the whole-of-society interface.

3.2.3. Preventive and Proactive Management

In Singapore, the proactive management of disease hosts and vectors is a public health priority. Though this is true for other One Health threats, this is seen most in efforts to control dengue. This approach is most apparent in the NEA's Wolbachia project [28], which focuses on using Wolbachia-Aedes suppression technology to reduce the mosquito population. This was performed after extensive studies by the NEA's Environmental Health Institute on novel mosquito control methods, after which Wolbachia-Aedes technology was identified as the most suitable strategy for Singapore's dense urban environment. Singapore thus uses this as a key preventive measure to reduce dengue in the population.

In addition to technological interventions, community engagement is a key part of Singapore's dengue prevention efforts [9]. Public education initiatives encourage residents and businesses to check for and eliminate potential mosquito breeding sites, such as unused containers, flower pots, and water storage. Fogging and fumigation are also conducted, particularly in high-risk areas, with a sparing approach to minimize the environmental impact. This combined strategy of technological, community, and environmental measures illustrates Singapore's strong preference for preventive and proactive vector management in support of its One Health objectives.

3.2.4. Prioritization of Surveillance and Early Detection

Singapore places a strong emphasis on surveillance and early detection across its health infrastructure, recognizing that it is far more challenging to control outbreaks once they have begun. Due to the country's dense population and small geographic size, infectious diseases can spread rapidly, making early intervention essential for effective containment.

To support these efforts, Singapore has implemented the Biosurveillance Framework, a national surveillance strategy designed to enhance the early detection of health threats. One key product of this framework is the Situational and Risk Assessment Report for One Health Hazards [29], published by the One Health Intelligence Team. This report provides timely information to all relevant One Health agencies and stakeholders on epidemic trends affecting the animal-human-water-environment interface. Each report is collaboratively developed by Singapore's five key One Health agencies, ensuring a unified approach to surveillance and enabling rapid, coordinated responses to potential health threats. This

framework exemplifies Singapore's proactive stance on surveillance, allowing for swift, evidence-based decision-making to mitigate risks before they escalate.

3.2.5. Partnerships with Regional and Global Bodies

Singapore's One Health strategy is bolstered by partnerships with regional and international networks, enabling enhanced surveillance and response capacities for zoonotic and other health threats. Singapore collaborates actively with organizations such as the World Health Organization (WHO), the World Organization for Animal Health (WOAH), and the Association of Southeast Asian Nations (ASEAN). These partnerships grant Singapore access to valuable resources, technical expertise, and best practices, ultimately improving the country's preparedness and resilience to potential zoonotic outbreaks.

In addition, Singapore recently established the Asia Centre for Health Security (ACHS) in April 2024 [30], a new think tank aimed at addressing existing health security gaps in the region and supporting ongoing efforts to prevent catastrophic biological threats, including zoonotic diseases and multidrug-resistant organisms [31]. The ACHS brings together a multidisciplinary team with expertise spanning public health, clinical practice, global health law, and policymaking. By fostering collaborative research and policy development, ACHS strengthens Singapore's One Health approach while contributing to broader regional and global health security initiatives.

3.2.6. Increased Emphasis on Research

Alongside the aforementioned strategies is Singapore's increasing emphasis on research relating to zoonotic diseases and AMR. Singapore actively encourages academic contributions to One Health and has demonstrated growing support through initiatives such as the establishment of the ACHS.

Additionally, the government has shown its commitment to expanding research efforts by enhancing funding opportunities for One Health-focused projects. For example, in 2022, the National Medical Research Council (NMRC) launched the One Health Antimicrobial Resistance Research Program (OHARP) Grant [32]. This grant initiative, jointly funded by the MOH, NEA, NParks, AVS, PUB, and SFA, is administered by the NCID. The OHARP supports research across human, animal, food, and environmental sectors to provide insights that inform national AMR policies and interventions. The program includes open research on AMR transmission pathways across multiple sectors and a commissioned study to assess the socioeconomic impact of AMR, including future projections if the issue remains unaddressed. Through initiatives like the OHARP, Singapore signals its commitment to strengthening research capabilities and fostering a data-driven approach to One Health challenges.

3.2.7. Training and Education

Training and education also encompass an essential strategy that Singapore uses to ensure the future security of the country. The Singapore Field Epidemiology Training Program (S-FETP) [33] is a partnership between the Saw Swee Hock School of Public Health and NCID and plays a pivotal role in this effort. S-FETP offers multi-sectoral, tiered training programs designed for professionals interested in field epidemiology and disease investigation. The programs go beyond human health to encompass hygiene, sanitation, environmental health, wildlife ecology, veterinary health, food safety, vector control, and social resilience. With robust support from the Ministry of Health, this training initiative has become an essential line of defense against emerging health threats. The S-FETP's approach not only emphasizes infectious disease epidemiology but also integrates key elements of One Health. Cross-disciplinary training equips professionals to understand and address health risks at the intersection of human, animal, and environmental health, strengthening overall resilience.

Additionally, the S-FETP published a book called “Communicable Diseases Control” [34] in 2020, which serves as a valuable tool for information dissemination, providing practitioners in Singapore with a comprehensive reference for managing and controlling communicable diseases. This educational framework ensures that Singapore’s One Health efforts remain sustainable, adaptive, and ready to meet evolving health challenges.

3.3. Gaps and Areas for Improvement

3.3.1. Inclusion of the Private Sector in One Health Efforts

The literature reveals a notable gap in collaboration between Singapore’s public health efforts and the private healthcare sector within the One Health framework. The private healthcare sector serves a significant portion of the population in Singapore, with many patients seeking healthcare services outside the public health system [35]. Without a structured partnership, the valuable data and resources within the private sector remain largely untapped in addressing One Health threats.

Beyond the private health sector specifically, the government can also engage other entities in the private sector. Chua et al. highlighted in one study [36] that there is an “incomplete surveillance system for AMR” across all sectors. Another study [4] by the same authors highlighted that there was a “lack of participation from certain sectors” in overall AMR efforts. Hence, leveraging private healthcare data on infectious diseases and zoonotic threats could enhance the national surveillance network, ensuring a more comprehensive picture of health trends and emerging risks across both public and private sectors. Incorporating the general private sector (healthcare-related or not) via engagement in One Health policies and programs could improve outbreak detection and enhance preparedness and response capabilities.

3.3.2. Insufficient Data Sharing Across Agencies

The literature review also revealed a lack of robust data-sharing mechanisms between agencies involved in One Health initiatives. For example, Chua et al. identified “constraints in information sharing” as a key gap in the National Action Plan on AMR [4]. Additionally, Singapore’s healthcare system operates the National Electronic Health Records (NEHR), which primarily consolidates patient information from hospitals and clinics. However, this excludes other relevant One Health-related institutions and sectors that could contribute valuable health data. More extensive data-sharing frameworks could improve coordination between health, agriculture, environmental, and veterinary agencies, providing a holistic view of health risks. Additionally, establishing non-sensitive data-sharing arrangements with regional and global health partners would strengthen collective surveillance efforts and improve regional preparedness against zoonotic and environmental health threats. To fully realize the potential of a One Health approach, a coordinated, cross-agency data-sharing strategy is essential.

3.3.3. Enhancing Community Engagement and Awareness of One Health

While the public is generally well-informed about individual diseases like dengue, our understanding of the broader One Health concept remains limited or not well-accepted [37]. Most community members may be unaware of the intricate links between human health, environmental factors, and animal health that underpin disease transmission. Building a more robust community engagement strategy that educates the public on One Health principles could foster greater understanding and cooperation in preventing zoonotic diseases and environmental health risks. Public health campaigns could highlight the connections between human health, ecological balance, and responsible interactions with animals, cultivating a more informed and proactive public that supports One Health

initiatives. This awareness is crucial for fostering community resilience and encouraging behaviors that reduce the risks of disease transmission in Singapore.

4. Discussion

4.1. Future Directions and Recommendations

4.1.1. Enhancing Cross-Sector Collaboration

To build a more resilient health system, Singapore can expand partnerships beyond the public sector, including the private healthcare sector and companies engaged in environmental initiatives. Integrating these sectors into the One Health strategy would provide a more comprehensive approach to disease prevention and control, leveraging private sector resources and expertise. Private healthcare providers could assist with disease surveillance and reporting, especially in areas where the public health system may have limited reach. Additionally, involving companies that impact environmental health—such as those in waste management, agriculture, and animal health—can help address the interconnected risks between human, animal, and environmental health. These partnerships could also help secure sustainable funding, share advanced technologies, and create an interdisciplinary approach to managing health threats, making the system more adaptable to future challenges.

4.1.2. Strengthening Data Sharing Networks

Effective public health response requires real-time, cross-border data sharing to anticipate and mitigate the spread of infectious diseases. Singapore can work toward establishing seamless data-sharing protocols with neighboring countries and global health organizations, allowing for early detection and response to health threats beyond its borders. Such collaboration could involve creating standardized data flows and interoperable systems that make it easier to share surveillance data, epidemiological findings, and pathogen genomics. Regional and global data sharing would not only strengthen disease monitoring but also foster collaboration on research, enabling Singapore to contribute to and benefit from global public health intelligence. This initiative could build upon existing relationships with organizations like the WHO, ASEAN, and other regional health bodies, potentially establishing Singapore as a hub for regional health data and intelligence.

4.1.3. Expanding One Health Education and Awareness

Increasing public awareness and professional training around One Health concepts can prepare Singapore's population and workforce for emerging health threats. Increasing funding to and expanding education programs like the aforementioned S-FETP would provide specialized training in One Health disease surveillance, outbreak management, and risk assessment, building a workforce capable of responding to complex health crises. Beyond professional education, public awareness campaigns that explain the interconnectedness of human, animal, and environmental health could foster a more informed public that supports and participates in One Health initiatives. Schools, universities, and community programs could incorporate One Health education to create a culture of awareness, preparing future generations to be proactive in health security efforts.

4.1.4. Sustaining and Increasing Investment in Public Health and Preventive Medicine

The COVID-19 pandemic highlighted the critical importance of robust public health infrastructure and preventive medicine. To maintain this momentum, Singapore should continue investing in infrastructure, resources, and policies that prioritize disease prevention. This investment includes expanding preventive health programs, enhancing laboratory and diagnostic capacities, and supporting research on emerging health threats. Long-term investments in workforce development, such as training healthcare professionals

in preventive medicine, would reinforce Singapore's public health capacity. Additionally, ensuring consistent funding for health education and preventive care initiatives would keep the public engaged in health maintenance, reducing the burden on healthcare systems and promoting a culture of proactive health management.

4.1.5. Building Regional One Health Capacities Collaboratively

Singapore already contributes to regional health security through academic institutions like ACHS. Expanding this role to include regional capacity-building initiatives, such as helping neighboring countries develop their own surveillance and response systems, would further enhance health security across Southeast Asia. This, in turn, would enhance Singapore's ability to perform forward defense when it comes to threats like zoonotic disease spread. This could involve cross-training platforms or collaborative projects, allowing countries to exchange best practices and develop shared response strategies. For instance, Singapore could host regular workshops like the recently completed Urban Health Security Workshop [38], which successfully brought together professionals from all over the globe to discuss urban health security and One Health challenges. By sharing expertise in areas like risk communication, outbreak response, and policy implementation, Singapore can play a crucial role in strengthening the region's overall preparedness.

4.1.6. Integrating Artificial Intelligence and Machine Learning in Surveillance

Artificial intelligence (AI) and machine learning (ML) offer powerful tools for enhancing disease surveillance and response. Singapore could implement AI-driven systems to analyze large volumes of health data, predict outbreak patterns, and identify at-risk populations more accurately. These technologies could be integrated with existing surveillance systems to detect anomalies and provide real-time insights. For example, AI algorithms could analyze syndromic data to identify early signs of an outbreak, enabling quicker responses. Machine learning models can also help optimize resource allocation by predicting areas of higher risk, allowing health authorities to prioritize surveillance and prevention efforts more effectively. Investing in AI and ML capabilities would not only make Singapore's surveillance system more efficient but also enable proactive rather than reactive health strategies. Furthermore, they could reduce reliance on manual human surveillance work.

4.2. Limitations

Several limitations should be noted for this paper. First, this paper is not a systematic review. Instead, it aims to offer a broad summary of the existing literature and grey literature relevant to Singapore's One Health framework. Consequently, the search methodology was not designed to be exhaustive, and some relevant studies or reports may not have been included.

Second, the breadth of this overview inherently limits the depth of analysis for any single strategy or intervention. While the paper highlights key initiatives, it does not provide detailed evaluations or in-depth analyses of their implementation or outcomes.

Third, the paper relies significantly on grey literature, such as government reports and policy documents, to complement findings from academic sources. While these materials offer valuable contextual insights, they may lack the rigor of peer-reviewed studies and could introduce biases or incompleteness in representing the broader One Health landscape in Singapore.

Additionally, the findings and recommendations in this paper are specific to Singapore's unique context as a dense urban environment and global trade hub. Because of its scope, this paper lacks a detailed comparison with One Health strategies implemented in other countries facing similar challenges. For example, countries like Hong Kong and the Netherlands have developed robust One Health frameworks that leverage cross-sector

collaboration and regional partnerships to address zoonotic diseases and antimicrobial resistance. Examining other countries' systems could provide valuable lessons that could inform Singapore's approach. Including such comparisons would also offer a broader perspective and highlight areas where Singapore's strategy aligns with or differs from other models, providing additional insights for improvement.

Lastly, this paper primarily synthesizes information from the existing literature and does not incorporate primary research or new empirical data. As a result, the conclusions drawn are reliant on the quality and availability of the reviewed sources.

Despite these limitations, the paper provides a foundational overview of Singapore's One Health strategy, identifying key strengths, challenges, and areas for improvement. It aims to stimulate further research and policy discussions to enhance the implementation of One Health approaches in Singapore and beyond.

5. Conclusions

Singapore's One Health approach exemplifies a strong, integrated framework that addresses the interconnected challenges of human, animal, and environmental health. With its dense urban environment, high population mobility, and role as a global trade and travel hub, Singapore is uniquely positioned to lead regional and international efforts to combat zoonotic diseases and other emerging health threats. However, as this paper highlights, there are areas for improvement that must be addressed to enhance Singapore's readiness and resilience. By building on its existing strengths and addressing identified gaps, Singapore can serve as a global model for implementing the One Health framework, especially for similar space-constrained, highly dense global cities.

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