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Designing Effective Regulations on Rabies Control in Tropical Regions: A Systematic Literature Review

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Abstract: Rabies, a global public health issue with a 100% mortality rate, affects tens of thousands annually, primarily in tropical regions, and is widespread in over 150 regions. Effective rabies control regulations are crucial in tropical regions due to limited healthcare, dense population, and virus-carrying species, promoting well-being, reducing costs, and promoting sustainability. This article aims to design effective regulations on rabies control in tropical regions. The study utilized a systematic literature review to explore effective rabies control in tropical regions. The analysis used Publish and Perish 8 tool and Mendeley Reference Manager software. The PRISMA was employed to guide the investigation. The study identified 26 significant research articles from 357 exclusions. The results reveal that pet rabies regulations may not effectively control outbreaks, requiring prioritizing awareness campaigns due to resource constraints, weak healthcare systems, and cultural factors in tropical regions. Therefore, the design of effective regulations on rabies control in tropical regions highlight: vaccination programs targeting pet domestications; reducing risk of rabies transmission through domesticated livestock; including rules on control, risk regulation, and animal population control; outlining minimum standards for health facilities and veterinary services; retraining healthcare workers and veterinarians involved in rabies prevention is necessary.

Keyword: Rabies Control, Rabies Regulations, Tropical Regions.

INTRODUCTION

Rabies still poses a great threat to public health owing to its zoonotic nature. Once clinical signs appear, the case fatality rate of this acute infectious (Nayak et al., 2022), centric disease reaches an approximate 100% (Moore, 2019). Rabies virus is transferred from an infected animal to a human being through an RAI bite. Rabies is the deadliest infectious disease that strikes the globe in a flood every year with tens of thousands of deaths (Duarte et al., 2021), Asia (Jane Ling et al., 2023; Miranda & Miranda, 2020) and Africa (Haselbeck et al., 2021; Nyasulu et al., 2021) being the worst hit by the disease. It has caused an average of 35172 cases of rabies

death in Asia each year. In 99% of the cases, it is pet dogs that act as the primary species of rabies virus transmitters to humans. Additionally, cats, ferrets, horses, raccoons, foxes, and monkeys can be contaminated and carry the disease also.

There is a consensus on the public health importance of rabies, with formal endorsements in different areas. It is imperative to avoid rabies since all of its cases lead to deaths. The success of the dog vaccination program depends on the willingness of the dog's caretakers to participate vigorously (Moore, 2019). As such, many factors may affect that decision-taking processes, such as: knowledge and experience, regulations, organizations and communities (Jeon et al., 2019). Climatic factors, biodiversity, population and healthcare services are among the factors that affect rabies outbreaks in the tropical parts (Gundamaraju et al., 2015). Potential vectors include feral or if stray pets such as dogs or cats, bats, wild animals (Jeon et al., 2019). Based on those reasons, many of the causes include stray animal exposure, inadequate health system vaccination protocols and virus prevention guidelines among the individuals. Tropical locations where rabies is relatively abundant can control incidence through interventions like vaccination of at-risk populations or strategic deployment of rabies vaccination for feral dog populations in targeted areas. From an epidemiological perspective, rabies is more often observed in tropical regions due to the presence of more rabies susceptibility animals, particularly dogs, and the corresponding effects of human-dog-rabies ecosystems (Ahmad et al., 2021; Arias Caicedo et al., 2019; Jiang et al., 2024; Léchenne et al., 2019). Understanding these statistical aspects of rabies cases is crucial for tailoring prevention and control measures, optimizing surveillance and reporting mechanisms, and averting the impact of rabies on human and animal populations in these regions.

The implementation of adequate regulations in rabies control plays a crucial role in establishing rabies control regulations, which have become the benchmark for program execution in many tropical regions (Moore, 2019). These regulations govern the prevention, control, and oversight of HPR (both maintenance and distribution), as well as the monitoring and supervision of program execution until the goal of eradicating cases is accomplished. One of those is the examination and enforcement of regulations on rabies control in the tropical areas. The control of rabies disease is limited due to inadequate healthcare prevention strategies (Acharya et al., 2020), the presence of various rabies-carrying animals (Prasanjaya et al., 2020), and population concentration in certain tropical regions (Gundamaraju et al., 2015; Léchenne et al., 2019). In addition, this is also able to ease solving issues, which are peculiar to some places (Haselbeck et al., 2021; León et al., 2021; Rohde & Rupprecht, 2020). With sufficient research, individuals can participate in strategies preferably implementing actions aimed at coping up with reduced rabies incidents, or maybe total rabies elimination, thus limiting preventable deaths.

Regulations to control rabies effectively leads to a greater impact on the health of individuals and animals (African Health Organisation, 2020; Public Health of England, 2019; Tasmanian Department of Health, 2024). These regulations that are expected to lead to the elimination of rabies in the animals should also serve to limit the risk of rabies in household pets and wild animals. The rabies outbreaks in the tropical areas are not only devastating but also saddening economically, bearing high medical costs, low productive labor due to sickness and investment in prevention and management of rabies post infection (South Carolina Department of Health and Environmental Control, 2019). It is vital to relieve this economic burden by implementing cost-effective measures. Certain strategies for controlling rabies may ensure a much greater degree of sustainability. Research plays a crucial role in enabling the advancement of more efficient rabies prevention strategies, including vaccination (Jeon et al., 2019; Moore, 2019; Nyasulu et al., 2021), awareness campaigns (Acharya et al., 2020; Ahmad et al., 2021; Gundamaraju et al., 2015; Miranda & Miranda, 2020; Prasanjaya et al., 2020), and surveillance systems (Arias Caicedo et al., 2019; Pham et al., 2021; Swedberg et al., 2022). However, there

are still existing constraints that hamper progress. Thoroughly designed regulations will ensure the successful execution of Australia's prevention measures.

The data from these studies have determined that regulations significantly contribute to the prevention and management of rabies. Rabies is a highly infectious disease caused by rabies superfamily viruses, particularly in tropical regions where stray dogs and companion animals are prevalent. This increases the likelihood of contact with and spreading the virus to humans (Prasanjaya et al., 2020; Rupprecht & Salahuddin, 2019). The availability of Rabies PEP and PrEP may be limited in tropical regions, making a wider population susceptible (Quiambao et al., 2020). Communities lack knowledge about rabies and its prevention and treatment methods (Léchenne et al., 2019).

In tropical regions of the world, bats are some of the wild animals that commonly spread rabies zoonosis together with primates, which serve as a reservoir for the disease (León et al., 2021). These reservoir species may serve as a source of rabies transmission to humans by getting in contact with pet animals (Jane Ling et al., 2023). The way rabies is transmitted in the study areas is different from the transmission of rabies in temperate regions in that the mode of transmission is through bites and or infected wound from the rabies-infected animals.

Peripheral nerves then convey the virus to the muscle tissues of the brain. Strongly unmanaged feral dog populations in many developing areas commonly act as vectors of Rabies Virus in tropical areas (African Health Organisation, 2020). Rabies patients in tropical regions may be attacked by feral or pet dogs infected with rabies, and may acquire rabies through their bites (Jane Ling et al., 2023). Moreover, because of limited healthcare resources and management following exposure, they may have a higher chance of getting rabies (Haselbeck et al., 2021). Today’s climatic conditions in tropical regions are hot and humid which are well known to affect the survival and transmission patterns of rabies amongst the animals.

This situation is even exacerbated by the proximity of civilization to wildlife and more domestic animals in tropical regions where cities have been expanding at a startling rate, therefore necessitating many opportunities for rabies transmission to both humans and animals. In such urban areas with a dense population, rabies is known to spread within a short time. In certain remote villages in the tropical climatic zones, the physical distance of the individuals to the healthcare centers can be a hindrance, thereby extended while getting post exposure prophylaxis and treatment of rabies (African Health Organisation, 2020; Raynor, 2023; World Health Organization, 2024). This time lag may reduce the chances of effective treatment and prolong the course of disease. The efforts aimed at rabies elimination in the tropical regions where individuals and animals are at high risk depends on the approaches which include large scale dog rabies vaccination strategies (Miranda & Miranda, 2020; Rohde & Rupprecht, 2020), informing the society and the development of effective surveillance systems (León et al., 2021). In tropical areas, the epidemiology of rabies is rather complicated and calls for detailed analysis for ecological, environmental, social, and health systems aspects (Léchenne et al., 2019). By facing these the concerns by providing appropriate solutions, rabies epidemics in the tropics will be controlled, thereby protecting the individuals’s health in that region.

As the public knows nothing, such regulations may exclude rabies awareness campaigns among those who are most likely to get bitten or to take risks like more than what the campaign was designed for which primarily is to help in preventing more severe outcomes (Kisaka et al., 2020; Nyasulu et al., 2021; Penjor et al., 2019). Superset barriers can provide some inchoate components which can impede regulations on rabies control, Ghanain society units for health, animal welfare and local government as such necessitate harmonization or tubelining (Thiel, 2024). There exists a thin net of national defense which may restrict the effectiveness of some rabies management and prevention regulations by not providing the necessary support such as essential personnel and financial resources to rabies programs.

Insufficient oversight mechanisms, inadequate rabies case management relying on active case detection (Rupprecht et al., 2020), and rabies surveillance relying on passive reporting all contribute to the delay in investigating rabies outbreaks (Pham et al., 2021). The One Health concept of rabies strategy could fail if there is a lack of interprofessional collaboration and boundary disintegration among health, veterinary, and environmental actors (Capps, 2024; Pham et al., 2021).

In certain rabies reporting systems, data is not fully exploited which leads to underreporting of rabies cases, which is a problem. This may limit comprehension of the extent to which the disease worsens and may sway regulation initiatives tethering to evidence based approaches. Many regulations are not thoroughly accompanied by sustainability strategies such as financial mechanisms, capacity building strategies and community strategic engagement that ensure that rabies control measures remain effective in curbing the disease. Better regulation of the rabies control systems could to a large extent control rabies in the environment or completely eliminate rabies in a population. For this reason, it is necessary to include a public education program for reducing rabies transmission, siphon stray dogs, exercise budget limits on shooting dogs, close the gap between vaccination and culling, and establish international collaboration on rabies assessment.

METHOD

To achieve the objective of this study, a systematic literature review (SLR) method was empoyed to investigate published works related to the research topic. The primary focus was on effective regulations on rabies control on tropical regions. The Scopus and the Pubmed databases as widely recognized reference services were used to search for scientific articles in three categories, namely regulations on rabies, rabies controls, rabies in tropical regions. The study included relevant ideas and used the Publish and Perish 8 and Mendeley Reference Manager as two tools to conduct the analysis. Furthermore, some criteria of relevant ideas for inclusion and exclusion were also considered in the investigation. Finally, the full-text research articles retrieved from the Scopus the Pubmed databases underwent the PRISMA analysis by including identification, screening, acceptance.

In the process of systematic planning using Publish and Perish 8 with three categories, namely regulations on rabies, rabies controls, rabies in tropical regions. Table 1 presents the results of three categories by Publish and Perish 8.

Table 1. The results of Three Categories by Publish and Perish 8

No	Category	Number	
		Scopus	PubMed
1.	Regulations on rabies	191	0
2.	Rabies controls	200	49
3.	Rabies in tropical regions	42	0
Total		433	49

The systematic planning using Publish and Perish 8 on the Scopus and the PubMed databases between 2019 and 2024 resulted 000 papers. The category of regulations on rabies were resulted in papers. The category of rabies controls were resulted in papers. The category of rabies controls in tropical regions were resulted in papers. Furthermore, they were were gathered in the Mendeley Reference Manager folder, exported as "RIS" data. This way aimed to investigate the gathered papers which matched with criteria of relevant ideas for inclusion and exclusion and PRISMA Analysis.

The systematic literature review (SLR) method employed five primary stages for the selection of literature: 1) The chosen publication data consists of full-text research articles, excluding papers which formated as book reviews, theses, dissertations, book chapters, books, editorial

reports, reviews or proceedings; 2) The selection of the full-text articles was limited to those published within the last 5 years (2019-2024) and covered three categories that were previously determined, namely regulations on rabies, rabies controls, rabies in tropical regions; 3) When conducting the investigation, we exclusively relied on globally sourced data, specifically the Scopus and the PubMed database as reputable journals with a strong reputation; 4) the researchers utilized specific applications such as Publish or Perish 8, and Mendeley reference management to facilitate the precise search for full-text research articles; 5) to obtain comprehensive global data on the category that was previously determined, we opted to use the Scopus and the PubMed databases for their search for the full-text research articles.
The process of searching for scientific publications was broken down into a number of three categories that was previously determined. It included effective regulations on regulations on rabies, rabies controls, rabies in tropical regions. Figure 1 presents the distributed data connected to the inclusion and exclusion in literature selection the PRISMA analysis.

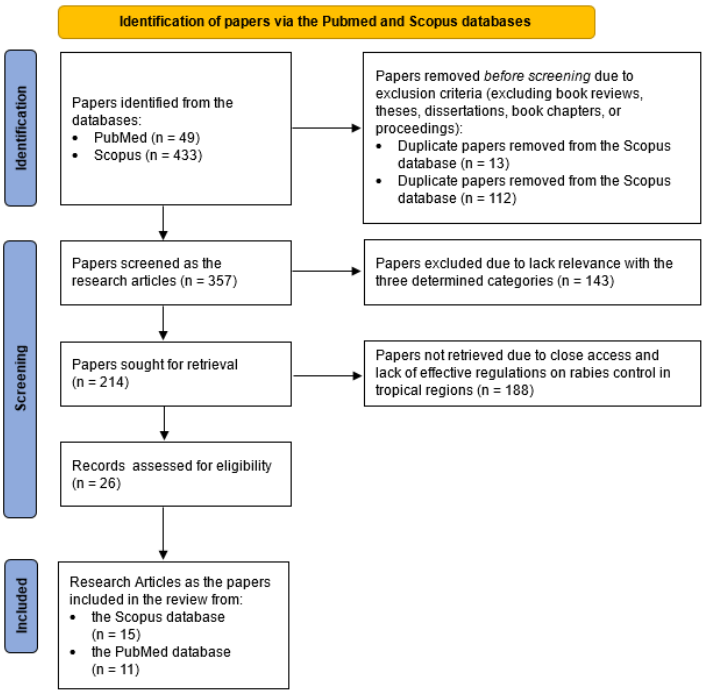

Figure 1. Article selection process based on the PRISMA systematic review flowchart

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RESULTS AND DISCUSSION

Regulations on Rabies

Pet rabies regulations may not always be the most effective method of controlling outbreaks, as noncompliance can lead to slackness and the transmission of the virus to animals or humans. The effectiveness of existing regulations and their degree of adherence are crucial factors in determining compliance (Neevel et al., 2020). Additional regulations may result in additional expenses for pet owners, economic stress, and loss of discretion regarding the progression of their dogs' diseases. Anti-rabies regulations are criticized for violating individuals' rights to engage in their preferred health practices and pet owners' rights to determine appropriate rehabilitation methods for their pets (Abdulazeez et al., 2020).

Regulation restrictions should not be excessively restrictive, as they could cause additional suffering for animals undergoing high-volume vaccinations or related procedures. The law prohibiting domestic animals from contracting rabies through vaccination may result in performance issues, as it may necessitate the administration of additional rabies injections or restrictions (Mauldin et al., 2022). Regulation will likely be challenging due to the existence of requirements specific to specific populations and regions, which may result in ambiguity regarding compliance over time. Partial implementation of regulations and measures can affect or impede rabies control, creating a window within which the disease may persist or even extend to certain territories (Ojedapo et al., 2020). To effectively manage rabies, some advocate for prioritizing education and awareness campaigns over strict regulations (Tu et al., 2020). The goal is to achieve individual responsibility and self-control, minimizing the extent of required overregulation while retaining the primary objective.

An integrated primary focus approach that takes into account public health requirements, individual rights, and animal rights is proposed. Education and awareness campaigns can spread knowledge about rabies, its spread, prevention methods, and the importance of vaccination, with free or low-cost vaccination clinics reaching targeted populations, especially in low-income societies (Schreuder et al., 2020). It may be necessary to modify regulations in order to comply with regional demands, different levels of income, and culture, as well as to allow provisions to be changed as appropriate. Reinforcing legal structures, employing electronic tools to register vaccination campaigns, and following up with non-compliant individuals can enhance action and punishment (Tasiame et al., 2022). Subsidies and support can range from partial co-funding of programs to complete financing of the immunization and preventative measures for the most disadvantaged group of pet animals (Dizon et al., 2022) by establishing connections between governmental agencies, private veterinarians, and the community that supports anti-rabies programs to enhance the management of rabies control (Briceño-Loaiza et al., 2024).

Collectively, these elements enable the effective elimination of rabies by implementing protective and sensitive laws tailored to the needs of the population.

Rabies Controls

Rabies is a public health issue that requires a comprehensive approach to prevent it in humans and animals. This includes a primary focus on public health requirements and individual and animal rights. Education campaigns can be used to raise awareness about rabies, its spread, prevention methods, and vaccination importance (Mshelbwala et al., 2024). Targeted populations can be reached through free or low-cost vaccination clinics, particularly in low-income societies. Regulations can be amended to meet regional needs and cultural differences (WHO Rabies Modelling Consortium, 2019). Compliance and enforcement mechanisms can be improved by strengthening regulatory frameworks, using electronic devices for vaccination records, and outreach to non-compliant individuals (Ahmad et al., 2021). Collaboration and partnerships can help develop organized rabies prevention efforts. Research and data analysis are crucial for ongoing evaluation of regulations and interventions. Community engagement can foster a sense of ownership for rabies (Haselbeck et al., 2021).

One of the primary disadvantages of the rabies control issue is that it pertains to cultural, environmental, animal, and health concerns. The implementation of economically viable and cost-effective pet vaccination programs can enhance the rate of vaccinations and reduce distributions (Bucher et al., 2023). Given the cultural practices and beliefs, stakeholder involvement is critical. Health information systems can integrate rabies case surveillance to halt the disease's spread in tropical regions (Dorji et al., 2023). We can employ trap-neuter-return methods in a humane manner to prevent feral animal populations. Wild animal management entails collaborating with wildlife control specialists to manage epidemics,

vaccines, and habitats (Rupprecht et al., 2023). Subsequently, funding research and improved monitoring and data control mechanisms may result in the development of novel technologies and styles, such as oral vaccines. A political system has the potential to promote and protect the welfare of animals, social and cultural ethics, individual rights and freedom, and public health. An approach that integrates government veterinarians, conservators, and non-governmental organizations is also an option (Williams et al., 2019). By integrating these and other factors into a comprehensive approach, we will establish effective and sustainable rabies management regulations, ultimately aiming to reduce rabies in both populations.

Rabies in Tropical Regions

Rabidity control in tropical regions is hindered by resources constraints (Leblanc et al., 2024), weak healthcare systems (Andriamandimby et al., 2023), lack of funding (Bahiru et al., 2022), and insufficient veterinary services (Naïssengar et al., 2021). These limitations increase the risk of rabies outbreaks and limit access to vaccine supplies, antirabies medication, rabies diagnostics, and therapy. High temperatures and humidity can aggravate product degradation and low activity of vaccines, making it difficult to maintain vaccine stability during storage and transport phases. To address this, active pharmaceutical alliance courier service should be implemented, incorporating proper storage systems, cool chain logistics, and monitoring systems. Rabidity spread among different animal species is also a challenge in tropical regions with a variety of animals (Naveenkumar et al., 2022). The large number of possible rabies reservoirs may enable rabies-free regions to be created globally. Rapid urban sprawl in the tropics may increase risk factors for zoonotic rabies due to greater overlap between urban landscapes used by non-human animals and their demand for nesting space, including humans and domestic animals. Cultural cognition of domestic animals and disease treatment may determine acceptance of rabies control measures, potentially leading to tensions if unregulated (Acharya et al., 2021).

To control rabies in the tropics, it is paramount to consider the environment, culture, socio-economics, and financial. The local population should be engaged in the formulation of activities, and vaccination campaigns may increase the uptake of the vaccine, thus preventing rabies (Kotzé et al., 2021). Wildlife management can also include the development of veterinary vaccination approaches for population groups at risk (Mshelbwala et al., 2022). Rabies surveillance controls the movements of animals within the herd and prevents the occurrence of outbreaks. Making available health care and veterinary services easier can help extend suitable vaccine use (Subedi et al., 2022). Health management measures as defined by law should be applied and appropriate controls adhered to. Different stakeholders are at times at variance, which can bring coordination of activities in the wildlife domain and the health sector (Bucher et al., 2023).

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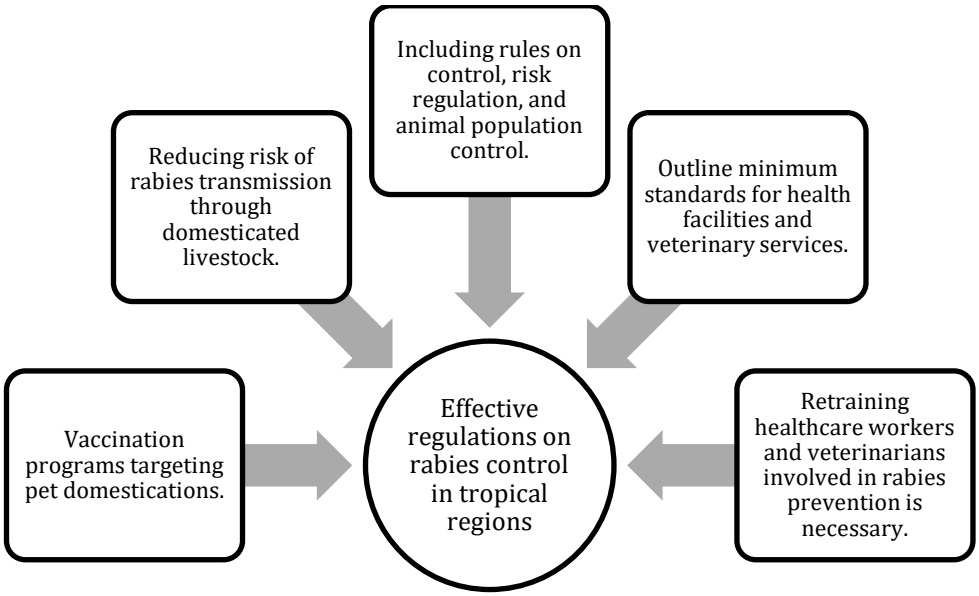

Figure 2. The Design of Effective Regulations on Rabies Control in Tropical Regions

CONCLUSION

Rabies regulations can be ineffective in controlling outbreaks, as noncompliance can lead to slackness and the transmission of the virus to animals or humans. To effectively manage rabies, education and awareness campaigns should be prioritized over strict regulations. An integrated approach that takes into account public health requirements, individual rights, and animal rights is proposed. This includes education campaigns, free or low-cost vaccination clinics, regulatory amendments, electronic tools, and outreach to non-compliant individuals. Subsidies and support can range from partial co-funding to complete financing for the most disadvantaged pet animal population. Collaboration and partnerships can help develop organized rabies prevention efforts. Despite challenges, a comprehensive approach involving government veterinarians, conservators, and non-governmental organizations can establish effective and sustainable rabies management regulations.

Rabies control in tropical regions is hindered by resources constraints, weak healthcare systems, lack of funding, and insufficient veterinary services. This increases the risk of rabies outbreaks and limits access to vaccine supplies, antirabies medication, and therapy. To address

this, active pharmaceutical alliance courier service should be implemented, and vaccine stability should be maintained during storage and transport phases. Rabidity spread among different animal species is also a challenge, and rapid urban sprawl may increase risk factors for zoonotic rabies. To accelerate rabies control, governments should initiate vaccination programs targeting pet domestications, regulate risk factors, and implement health frameworks. Cross-functional and cross-cultural teams should be created to address challenges and develop comprehensive plans for disease control targeting animals, humans, and the environment.

A systematic literature review on effective rabies control regulations in tropical areas faces several obstacles. The lack of comprehensive information on rabies control policies and their success can hinder the identification of relevant studies and the synthesis of results. Divergence in research designs, methodologies, outcomes, and directionality can also hinder comparisons and reading conclusions. Publication bias can negatively influence the findings of rabies control measures, as focus may be on research published in a particular language, resulting in a narrower population for the review. Homogenous findings cannot be assumed due to differences in study types, and factors like wildlife species, culture, and health systems may create barriers to the dissemination of results.

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