

## Urgent need for sustainable behavioral change interventions for effective control of rabies

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**To cite this article:** Francesco Branda, Krishna Prasad Acharya, Giancarlo Ceccarelli, Massimo Ciccozzi, Fabio Scarpa, Kailash Bohara, Jiyeon Oh & Dong Keon Yon (05 Nov 2024): Urgent need for sustainable behavioral change interventions for effective control of rabies, Infectious Diseases, DOI: [10.1080/23744235.2024.2423243](https://doi.org/10.1080/23744235.2024.2423243)

**To link to this article:** <https://doi.org/10.1080/23744235.2024.2423243>



Published online: 05 Nov 2024.



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## COMMENT



## Urgent need for sustainable behavioral change interventions for effective control of rabies

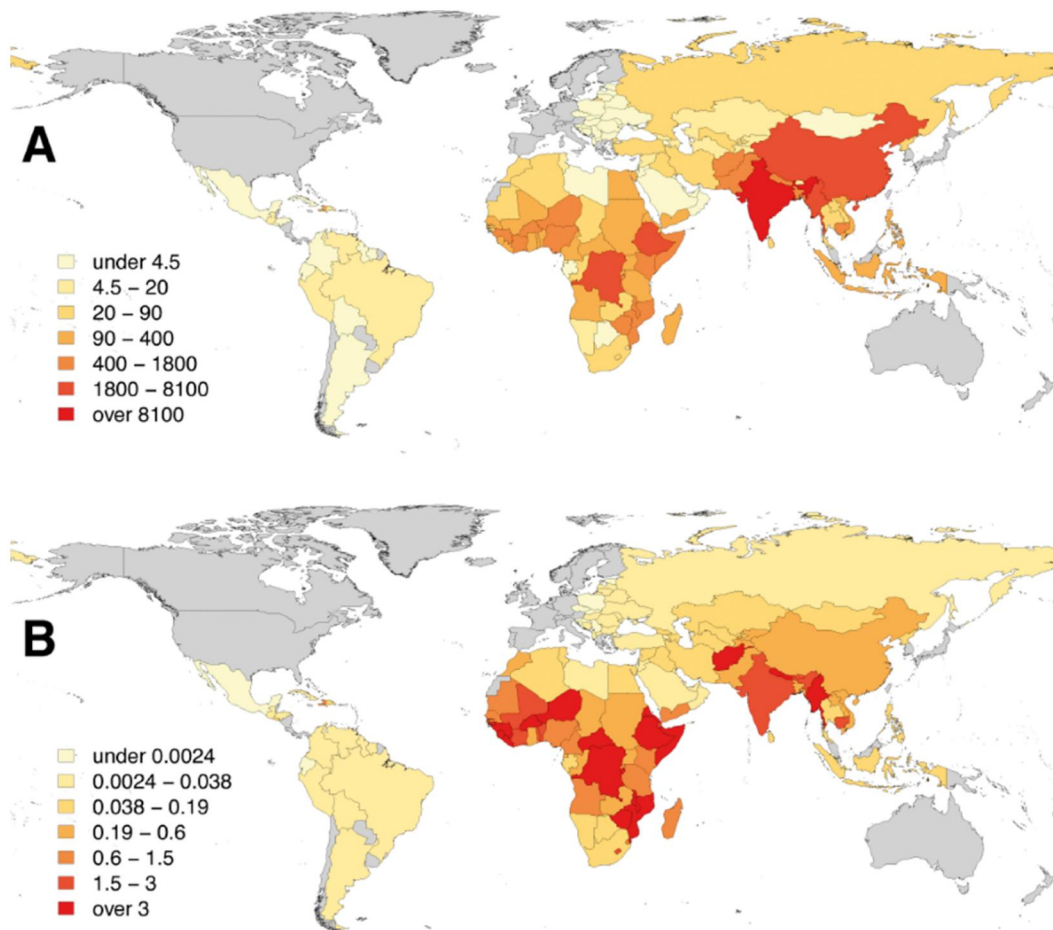
Rabies represents a significant public health challenge, particularly in low- and middle-income countries (LMICs) [1]. Although rabies control programs have been implemented in both developed and developing countries, the results have been mixed. In many developed countries, rabies has been effectively controlled through strategies such as mass awareness, pre-exposure and post-exposure prophylaxis (PEP), animal birth control, promotion of responsible pet ownership, and early detection, control, and prevention measures. However, LMICs remain endemic for rabies. Despite efforts, about 59,000 people and thousands of animals die from rabies globally each year, in more than 150 countries, with 95% of cases concentrated in Africa and Asia. However, due to widespread under-reporting and uncertain estimates, this number is believed to be a significant underestimate of the true impact of the disease. 99% of rabies cases are transmitted by dogs, and the burden of the disease falls disproportionately on poor rural populations [2]. **Figure 1** illustrates the global burden of human rabies transmitted by dogs through two complementary perspectives. **Figure 1(A)** represents the absolute number of human deaths due to rabies: the greatest burden is concentrated in Asia and Africa, with China and India showing the darkest red, exceeding 8,100 deaths per year. Some African countries, including Nigeria, Ethiopia and the Democratic Republic of Congo, are highlighted in dark orange, indicating between 1,800 and 8,100 annual deaths. Much of South America, North Africa and Southeast Asia are in the yellow to light orange range, signaling a smaller but still significant number of deaths. Developed regions, such as North America, Europe and Australia, appear in light yellow or gray, indicating very few or no deaths from rabies. **Figure 1(B)**, on the other hand, presents per capita mortality rates, offering a different perspective: this map highlights the disproportionate impact on African countries, with several countries in dark red showing mortality rates below three per 100,000 population. India also remains a

hotspot, while China's impact seems less severe when population size is considered. This per capita view highlights the higher relative risk in some small African nations that may not stand out in the absolute death map. Finally, the gray coloring of many developed countries confirms their status as rabies-free nations, underscoring the global inequality in the distribution of the disease burden.

These numbers raise questions about the effectiveness of programs currently in place. Countries have adopted various strategies to prevent and control rabies, but instead of reducing the incidence of the disease, an increase has been observed in recent years. This increase in cases, despite control programs, highlights a significant gap in the current approach, particularly in less developed countries. A crucial element that seems to have been overlooked is the integration of sustainable behavioral interventions, which could prove particularly effective and cost-effective in reducing rabies virus transmission.

Numerous studies have shown that people's perception of risk directly influences their behavior (see **Table 1**), prompting them to take preventive and control measures [3]. Since human behavior is a major cause of the maintenance and spread of rabies [4], changing such behaviors is essential to prevent transmission of the virus [5]. This goal requires behavioral change interventions that are durable and adaptive. Interventions could include several strategies, such as education, persuasion, incentive, coercion, enablement, training, restriction, environmental restructuring and behavior modeling, as suggested by West and coworkers [6]. Such interventions could inform more effective policies to: reduce infection rates, implement stricter control measures and develop new resilient behaviors that can prevent future rabies outbreaks.

A critical aspect of these interventions is to ensure that behavioral change is not only temporary but is maintained over time. It is essential that communities not only adopt new behaviors but also adhere to them



**Figure 1.** Global burden of dog-transmitted human rabies. (A) Human deaths from rabies. (B) Death rates per capita (per 100,000 population); countries shaded in grey are free from canine rabies. Source: <https://www.who.int/teams/control-of-neglected-tropical-diseases/rabies/epidemiology-and-burden>.

**Table 1.** Virtuous and counterproductive behaviors for rabies control: evidence from the scientific literature.

Virtuous behaviors	Counterproductive behaviors	References
Regular vaccination of domestic dogs and cats	Do not vaccinate pets	Lembo, T., et al. 'The feasibility of canine rabies elimination in Africa: dispelling doubts with data.' <i>PLoS Neglected Tropical Diseases</i> (2010).
Education on how to interact safely with dogs (especially children)	Approaching stray or unknown dogs without precautions	Knobel, D. L., et al. 'Reevaluating the burden of rabies in Africa and Asia.' <i>Bulletin of the World Health Organization</i> (2005).
Bite prevention through teaching warning signs in dogs	Provoking or annoying dogs, especially in stressful situations	Cleaveland, S., et al. 'The conservation relevance of epidemiological research into carnivore viral diseases in the Serengeti.' <i>Conservation Biology</i> (2006).
Promotion of sterilization to reduce the stray dog population PEP after biting	Ignoring or mistreating stray dogs Neglect bite wounds and do not undergo post-exposure care	Hampson, K., et al. 'Estimating the global burden of endemic canine rabies.' <i>PLoS Neglected Tropical Diseases</i> (2015). Hampson, K., et al. 'Transmission dynamics and prospects for the elimination of canine rabies.' <i>PLoS Biology</i> (2008).
Promotion of responsible pet ownership practices	Abandonment or neglect of pets	Fahriani, A. S., et al. 'The road to dog rabies control and elimination—what keeps us from moving faster?' <i>Frontiers in Public Health</i> (2017).
Intersectoral collaboration for rabies prevention and control	Lack of coordination between public health and veterinary sectors	WHO, World Health Organization. 'Zero by 30: the global strategic plan to end human deaths from dog-mediated rabies by 2030.' (2018).
Timely and correct treatment of dog bites	Delaying or neglecting treatment of bite wounds	Cleaveland, S., et al. 'One Health contributions towards more effective and equitable approaches to health in low- and middle-income countries.' <i>Philosophical Transactions of the Royal Society B: Biological Sciences</i> (2017); Wilde, H., et al. 'Rabies in Asia: the classical zoonosis.' <i>Indian Journal of Pediatrics</i> (2007).
Humanitarian control of the stray dog population	Consumption of dog meat without considering the risks of rabies transmission	Taylor, L. H., et al. 'Eliminating canine rabies: the role of public-private partnerships.' <i>Antiviral Research</i> (2017).

to reduce the risk of virus transmission [7]. However, despite the importance of behavioral change, there is a dearth of data and evidence demonstrating the effectiveness of such interventions in controlling rabies [8], especially in LMIC settings. Understanding the factors driving behavioral change and their impact on rabies control is critical to developing evidence-based policies. In LMICs, where resources are limited, it is essential that behavioral interventions are not only effective but also affordable. Limited resources often hinder disease control programs, including rabies [9]. Therefore, available evidence should be shared publicly to enable other countries to adapt and adopt appropriate behavioral change tools. In addition to traditional control measures, rabies prevention and control programs should incorporate behavioral interventions that address specific human behavior problems. Such interventions should involve significant numbers of individuals in at-risk communities and include the mobilization of local and religious leaders, figures who can exert decisive influence in promoting the change necessary to successfully interrupt rabies transmission.

An additional obstacle to rabies control in developing countries is human attitudes toward stray dogs. In many regions of Asia and Africa, stray dogs are often neglected or mistreated by humans. In particular, children, who tend to play with and provoke these animals, are at greater risk of bites from infected dogs [10]. Provocation increases aggression in dogs, which respond to attitudes perceived as threats with attacks or bites [11]. Often, people fail to recognize the warning signals given by dogs, such as growling or maintaining a stiff posture, and make mistakes such as approaching a mother with puppies or a sleeping dog. These mistakes, especially common among children, can easily lead to a dog bite [12].

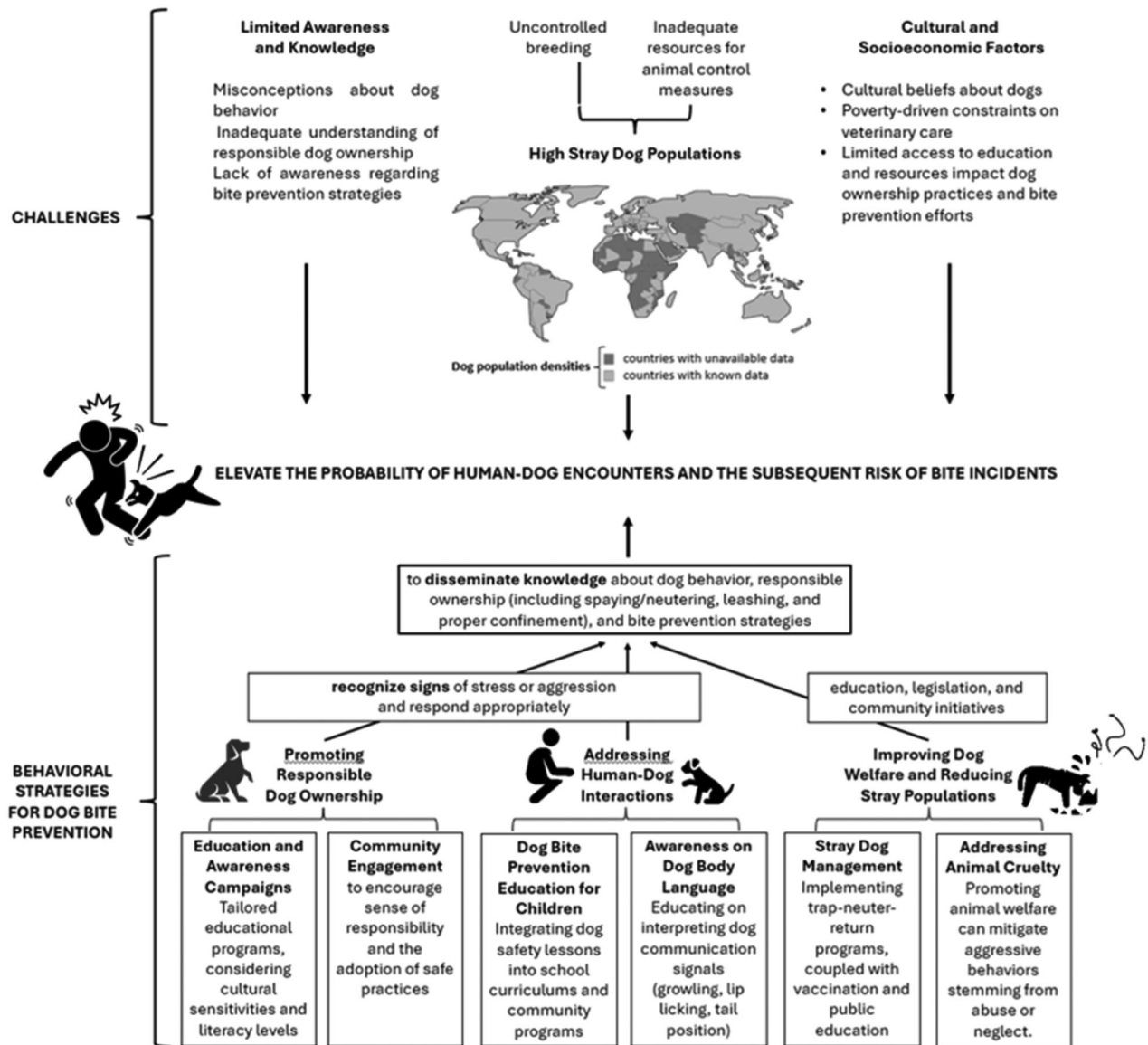
Another factor contributing to the spread of rabies in some Asian countries is the consumption of dog meat. A study conducted in Vietnam found that butchers who work with infected dogs are particularly at risk of contracting rabies [13]. Many of these butchers, 91.9% are not vaccinated against rabies, often because of fear of side effects, economic problems or misunderstandings about preventing the disease [14]. In addition, in China, although the country produces and consumes the largest number of rabies vaccines in the world [15], dog bite wounds are often inadequately treated and post-exposure prophylaxis is neglected, indicating a lack of awareness of the severity of the disease.

Lack of resources and knowledge negatively affects public perception of rabies control. In many regions where access to vaccination and medical care is limited, dog bite victims tend to turn to traditional healers, an ineffective approach to treating the disease [16, 17]. It is critical to change the public's perception of dogs, dog bites and rabies transmission through education to mitigate these problems.

However, as pointed out earlier, changing individual behaviors is not enough; it needs to be complemented by expanding preventive tools, increasing diagnostic tests and treatment options, and strengthening surveillance systems, all supported by strong political commitment and multisectoral collaboration. Until the necessary changes in attitudes and behaviors of institutions and personnel are addressed, these issues will continue to hinder the effective implementation of rabies control programs. It is therefore crucial that authorities and funders find ways to better support behavioral change, recognizing that without a radical change in the attitudes of the practitioners involved, it will be impossible to effectively address the anger problem.

Rabies control programs should also include interventions aimed at behavioral change that can effectively reduce rabies virus transmission. Further research is needed to identify the most effective behavioral interventions and understand their implications under real-world conditions [15]. Countries are therefore urged to pay more attention to behavioral change as a practical measure to advance rabies control. Considering the lack of emphasis on behavioral change and the ineffectiveness of current control programs, it is essential to implement a system that promotes behavioral change. Only by changing the behavior of stakeholders can rabies control programs be successfully implemented and ultimately eliminate the disease.

In conclusion, mitigating the risk of dog bites in developing countries requires a multifaceted approach that extends beyond traditional public health interventions (Figure 2). Behavioral strategies, based on a One Health perspective, are fundamental to achieving sustainable solutions. This necessitates fostering responsible dog ownership practices, enhancing community knowledge and awareness regarding safe human–dog interactions, and implementing humane and effective stray dog management programs. Crucially, the success of these endeavors hinges on robust intersectoral collaboration, ensuring that public health officials, veterinarians, animal welfare organizations, educators and



**Figure 2.** Challenges and behavioral strategies in dog bite prevention within developing countries: a One Health Lens. The global map illustrating the data gap in the estimated frequency of dogs per 1000 people. Darker shaded regions represent countries where data were unavailable, while grey shaded areas indicate countries with known dog population densities [18].

community members work in concert. By embracing community-based participatory approaches, interventions can be tailored to the unique cultural and socio-economic contexts of each region, fostering ownership and sustainability. Ultimately, a unified approach that recognizes the interconnectedness of human, animal and environmental health.

### Author contributions

Francesco Branda: investigation, visualization, writing – original draft, writing – review and editing. Krishna Prasad Acharya: conceptualization, investigation, writing – original draft, writing – review and editing. Giancarlo Ceccarelli: investigation, writing – original draft, writing – review and editing. Fabio Scarpa:

investigation, writing – original draft, writing – review and editing. Massimo Ciccozzi: validation, supervision, writing – original draft, writing – review and editing. Kailash Bohara: investigation, writing – original draft, writing – review and editing. Jiyeon Oh: investigation, writing – original draft, writing – review and editing. Dong Keon Yon: validation, supervision, writing – original draft, writing – review and editing.

### Disclosure statement

No potential conflict of interest was reported by the author(s).

### Funding

None.

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Received 22 October 2024; accepted 25 October 2024

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