Review Article

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Vaccination and disease prevention protocols for pets: A review

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ABSTRACT

Vaccination and disease prevention strategies are essential interventions for maintaining the health of companion animals and reducing the risk of zoonotic disease transmission to humans. The effectiveness of these programs relies on the proper implementation of vaccination protocols, environmental management, parasite control, nutritional support, and owner education. This review summarizes current vaccination protocols and complementary non-vaccination preventive measures for dogs and cats. It outlines the classification of core and non-core vaccines, vaccination schedules for puppies and adult animals, booster recommendations, and factors influencing immunization efficacy. Recent advancements in vaccine development, such as recombinant and mRNA-based technologies, are also discussed for their potential to enhance safety and immunogenicity. Beyond vaccination, this review addresses non-immunization preventive strategies, including kennel hygiene and environmental sanitation, biosecurity in veterinary and boarding facilities, ecto- and endoparasite management, and nutritional approaches to strengthen immune function. Owner education is emphasized as a critical component in improving compliance with vaccination schedules and preventive health practices. The review concludes that integrating vaccination with non-vaccination preventive measures strengthens both individual and herd immunity, reduces the incidence of infectious diseases, and minimizes zoonotic risks. Current challenges include pathogen variation, inconsistent owner compliance, regional disparities in vaccination policies, and the ongoing need for safer and more effective vaccines. Advances in vaccine technology and personalized immunization strategies provide new opportunities to improve the efficacy, safety, and sustainability of pet health programs.

Introduction

Pet health constitutes a fundamental component of public health, particularly within the framework of the One Health concept, which underscores the interconnection among human, animal, and environmental health (Zinsstag *et al*., 2023). Companion animals such as dogs and cats play a significant role in human society, not only as sources of companionship and emotional well-being but also as potential reservoirs for infectious pathogens (Esposito *et al*., 2023). The close and frequent interactions between humans and pets heighten the risk of zoonotic disease transmission, including rabies, leptospirosis, and toxoplasmosis, thereby necessitating systematic and integrated disease prevention strategies (Shaheen, 2022). Maintaining the health of companion animals, therefore, is essential not only for ensuring animal welfare but also for safeguarding broader public health security (McDowall *et al*., 2023).

A major concern commonly encountered in animal health management is the high prevalence of infectious diseases that can be transmitted both among animals and between animals and humans (Clemmons *et al*., 2021; Kurniawan *et al*., 2025). In dogs, viral infections such as canine distemper, parvovirus, and rabies remain serious threats, with high mortality rates particularly among unvaccinated individuals (Rivera-Martínez *et al*., 2024). Similarly, in cats, infections such as feline panleukopenia, calicivirus, and rhinotracheitis are frequently reported as primary causes of morbidity, leading to reduced quality of life (Hofmann-Lehmann *et al*., 2022). Beyond viral diseases, bacterial infections, including bordetellosis and leptospirosis, also pose substantial clinical and epidemiological challenges (Sykes *et al*., 2022). These issues are further compounded by low public awareness regarding the importance of vaccination and by limited access to adequate veterinary healthcare services in certain regions (Borah *et al*., 2025).

Vaccination represents one of the most effective preventive strategies for controlling infectious diseases in companion animals (Warimwe *et al*., 2021). It provides immunological protection that not only reduces the likelihood of infection but also mitigates disease severity upon exposure (Pollard and Bijker, 2021). The classification of vaccines into core and non-core categories has been established to differentiate between those that are universally recommended for all animals, such as rabies and distemper in dogs, or panleukopenia in cats, and those administered only under specific risk conditions, such as leptospirosis or bordetellosis (Entrican and Francis, 2022). The implementation of standardized vaccination protocols effectively decreases disease incidence and contributes to the development of herd immunity within pet populations, thereby lowering the potential for zoonotic transmission to humans (Carpenter *et al*., 2022).

This review aimed to provide a comprehensive synthesis of vaccination protocols and disease prevention strategies in pets, with an emphasis on their relevance to public health. It discusses major infectious diseases, fundamental principles of immunization, vaccination schedules, and complementary non-vaccination preventive measures that support animal health. Furthermore, the article highlights current challenges in vaccination implementation, including owner compliance, regional regu-

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latory discrepancies, and the emergence of next-generation vaccines. The novelty of this review lies in its integrative approach, which connects pet vaccination protocols with the One Health framework, offering a broader understanding of the significance of preventive interventions not only for animal welfare but also for human health protection. Accordingly, this review is expected to serve as a valuable reference for veterinary clinical practice and as a foundation for the development of prevention-oriented public health policies.

Major diseases in pets

Pets are susceptible to various infectious diseases that can affect individual and population health (Shaheen, 2022). These diseases (Table 1) can originate from viruses, bacteria, parasites, or zoonotic agents that have the potential to be transmitted to humans (Al Sulivany *et al*., 2024). Understanding the characteristics, transmission mechanisms, and clinical impacts of each disease group is essential for designing effective vaccination protocols and prevention strategies (Branda *et al*., 2024).

Viral diseases

Diseases caused by viruses are one of the main threats to pet health due to their high transmission rate and potential to cause death, especially in young or unvaccinated animals (Squires *et al*., 2024). In dogs, rabies is particularly significant because it is zoonotic with a fatality rate of nearly 100% after clinical symptoms appear (Das *et al*., 2025). The rabies virus attacks the central nervous system and causes progressive neurological disorders leading to death (Fatima *et al*., 2023). Prevention through routine vaccination of dogs has proven to be the most effective strategy for reducing the incidence of rabies in both animals and humans (Lugelo *et al*., 2022).

In addition to rabies, canine distemper virus (CDV) is also a significant viral disease in dogs (Thibault *et al*., 2022). This virus attacks the respiratory, gastrointestinal, and nervous systems, causing multisystemic symptoms with a high mortality rate (Rivera-Martínez *et al*., 2024). Another equally important disease is canine parvovirus (CPV), which is characterized by severe gastroenteritis, dehydration, and leukopenia, especially in puppies (Decaro and Buonavoglia, 2012). CPV has high environmental resistance, often causing outbreaks in unvaccinated dog populations (Zhou *et al*., 2024).

In cats, feline panleukopenia virus (FPV) is a highly contagious viral disease with clinical manifestations including fever, vomiting, bloody diarrhea, and bone marrow suppression leading to a drastic decrease in leukocyte count (Awad *et al*., 2018). FPV mortality is quite high, especially in kittens. In addition, feline calicivirus (FCV) is the main agent of upper respiratory tract disease in cats with symptoms of oral ulceration, conjunctivitis, and respiratory distress (Di Profio *et al*., 2025). This disease is often chronic or recurrent, affecting the animal's quality of life in the long term (Hofmann-Lehmann *et al*., 2022).

Bacterial diseases

In addition to viral infections, diseases caused by bacteria also pose a major challenge to pet health. Some of these diseases are zoonotic, posing a direct risk to human health (Socha *et al*., 2022). Leptospirosis, caused by Leptospira interrogans, is one of the most important bacterial diseases in dogs (Vyn *et al*., 2024). This agent can be transmitted through contact with water or soil contaminated with the urine of infected animals (Khairullah *et al*., 2024). Clinical symptoms in dogs include fever, anorexia, vomiting, jaundice, and acute kidney failure (Vyn *et al*., 2024). Due to its zoonotic nature, leptospirosis is a priority disease that requires strict control, both through vaccination and hygienic environmental management (Sykes *et al*., 2022). Non-core leptospira vaccines are available and recommended in endemic areas to reduce the incidence of this disease (Malter *et al*., 2022).

Bordetellosis, caused by *Bordetella bronchiseptica*, is also a common bacterial disease in dogs and cats, especially in environments with high animal density such as shelters, kennels, or boarding facilities (Hadzevych, 2024; Jang *et al*., 2025). This infection is known as one of the main causes of canine infectious respiratory disease complex (CIRD), characterized by

Table 1. Major diseases in pets, causative agents, clinical symptoms, transmission routes, and prevention strategies.

Disease categories	Examples of diseases	Causative agent	Primary clinical symptoms	Transmission	Prevention	Source
Viral	Rabies (dog)	Rabies virus	Progressive neurological disorders and death	Bites from infected animals	Routine vaccinations and owner education	(Das *et al*., 2025)
	Canine Distemper Virus (dog)	CDV	Multisystemic symptoms: respiratory, gastrointestinal, and neurological	Direct contact and aerosol	Core vaccination	(Rivera-Martínez *et al*., 2024)
	Canine Parvovirus (dog)	CPV	Severe gastroenteritis, dehydration, and leukopenia	Fecal-oral contact	Core vaccinations and environmental sanitation	(Zhou *et al*., 2024)
	Feline Panleukopenia Virus (cat)	FPV	Fever, vomiting, bloody diarrhea, and bone marrow suppression	Fecal-oral contact	Core vaccination	(Awad *et al*., 2018)
	Feline Calicivirus (cat)	FCV	Oral ulceration, conjunctivitis, and respiratory disorders	Direct contact and aerosol	Core vaccination	(Wei *et al*., 2024)
Bacteria	Leptospirosis (dog)	*Leptospira interrogans*	Fever, anorexia, vomiting, jaundice, and acute kidney failure	Water/soil contamination	Non-core vaccines in endemic areas and environmental sanitation	(Vyn *et al*., 2024)
	Bordetellosis (dog/cat)	*Bordetella bronchiseptica*	Dry cough, sneezing, and mild fever	Aerosol and direct contact	Non-core vaccinations and animal density management	(Hadzevych, 2024)
	Salmonella spp. and *E. coli*	Enteric bacteria	Enteritis and diarrhea	Fecal-oral	Environmental hygiene and biosecurity	(García-Díez *et al*., 2024)
	Pasteurella multocida	Bite wound bacteria	Wound infection and local inflammation	Animal bites	Wound cleanliness and owner education	(Shen *et al*., 2025)
Parasite	Lice, fleas, mites	Ectoparasite	Allergic dermatitis, anemia, and disease vectors	Direct contact and environment	Regular antiparasitic medication and environmental cleaning	(Deng *et al*., 2024)
	Toxocara canis/*cati*	Intestinal worm	Diarrhea, vomiting, and growth disorders	Fecal-oral	Regular deworming medication and hygiene management	(Ursache *et al*., 2021)
	Giardia duodenalis	Protozoa	Chronic diarrhea	Fecal-oral and environment	Administration of medication and environmental hygiene	(Ayed *et al*., 2024)

dry cough, sneezing, and sometimes accompanied by mild fever (Ouyang *et al*., 2024). Although rarely fatal, bordetellosis poses significant health issues due to its high contagiousness, potential to affect an animal's quality of life, and increased treatment costs (Serbessa *et al*., 2023).

In addition to these two main diseases, several other bacterial infections also have clinical relevance in pets. For example, *Salmonella* spp. and Escherichia coli can cause enteritis, while *Pasteurella multocida* is often found in cat bite wound infections and can be transmitted to humans (García-Díez *et al*., 2024; Nasrollahian *et al*., 2024). The presence of these bacteria underscores the urgency of implementing prevention strategies that not only rely on vaccination but also include biosecurity, environmental control, and educating pet owners about the risks of zoonoses (Carpenter *et al*., 2022).

Parasitic diseases that can be prevented through management and prevention

Parasitic infections remain an important health issue in pets because they can cause clinical disorders, reduce the quality of life of animals, and potentially become a source of zoonosis (Kaminsky and Mäser, 2025). Parasites in pets are generally divided into ectoparasites, such as fleas (*Ctenocephalides felis*), ticks (Rhipicephalus sanguineus), and mites, and endoparasites in the form of gastrointestinal worms and protozoa (Taddesse *et al*., 2024). The presence of these parasites often causes chronic diseases, growth disorders, and facilitates the transmission of other infectious agents through their vectorial role (Yadav and Upadhyay, 2023).

In dogs and cats, flea infestations not only cause allergic dermatitis due to bites, but also serve as vectors for *Dipylidium caninum* (tapeworm) and several bacterial agents such as *Bartonella henselae* (Rocha *et al*., 2025). Ticks play an important role as vectors for various diseases, including babesiosis and ehrlichiosis in dogs (Aziz *et al*., 2022). Heavy infestations can cause anemia, weakness, and decreased immunity, thereby increasing susceptibility to other diseases (Flay *et al*., 2022).

Endoparasites are also a significant concern. Intestinal worms such as *Toxocara canis* and *Toxocara cati* often infect dogs and cats, especially young individuals (Pal and Tolawak, 2023). These infections can cause diarrhea, vomiting, abdominal distension, and growth disorders (Khurana *et al*., 2021). Furthermore, Toxocara is zoonotic because its larvae can migrate in human tissues and cause visceral or ocular larva migrans syndrome (Huynh *et al*., 2024). In addition, protozoa such as *Giardia duodenalis* can cause chronic diarrhea in animals and are also transmissible to humans through environmental contamination (Dixon, 2021).

The strategy for preventing parasitic diseases in pets does not rely on vaccination, but rather on a combination of environmental management, biosecurity, and routine administration of antiparasitic drugs (Sander *et al*., 2020). Cleaning cages, controlling humidity, and regularly disposing of feces are simple yet effective steps to break the parasite life cycle (Olagunju, 2022). The use of modern antiparasitic drugs, whether oral, topical, or injectable, has been proven effective in controlling ectoparasite and endoparasite infestations (Selzer and Epe, 2021). Educating pet owners about deworming schedules, flea and tick prevention, and the importance of maintaining animal and environmental hygiene are key to the success of this program (Panchim *et al*., 2024). Figure 1 illustrates the major viral, bacterial, and parasitic diseases in pets and the core prevention measures (vaccination, hygiene/biosecurity, and routine parasite control).

Vaccination protocol for pets

Vaccination is one of the most effective preventive interventions in maintaining the health of pets, while also protecting the community from the threat of zoonoses (Carpenter *et al*., 2022). The implementation of a standardized vaccination protocol not only provides individual protection but also contributes to building herd immunity in animal populations (Bullen *et al*., 2023). To achieve optimal effectiveness, it is necessary to understand the basic principles of immunization, the selection of core and non-core vaccines, the determination of an appropriate vaccination

Table 2. Vaccination protocol for pets.

Category	Types of vaccines	Animal species	Prevention objectives	Vaccination schedule	Notes / Effectiveness factors	Source
Core	Rabies	Dog and Cat	Prevention of rabies zoonosis with a fatality rate of nearly 100%	Children: 12 weeks; Booster: every 1–3 years	Very important: recombinant or mRNA vaccines improve safety and efficacy	(Makovska *et al*., 2024)
	Canine Distemper Virus (CDV)	Dog	Multisystemic disease with high mortality	Children: 6–8, 10–12, 14–16 weeks; Booster: every 1–3 years	The immune response is influenced by maternal antibodies, nutrition, and health status	(Gonzalez *et al*., 2023)
	Canine Parvovirus (CPV-2)	Dog	Severe gastroenteritis in puppies	Just like CDV	Multivalent vaccines simplify administration	(Hernández *et al*., 2025)
	Canine Adenovirus tipe-2 (CAV-2)	Dog	Prevention of infectious hepatitis and respiratory tract infections	Just like CDV	Multivalence improves owner compliance	(Kumar *et al*., 2023)
	Feline Panleukopenia Virus (FPV)	Cat	Fatal panleukopenia in kittens	Children: 6–8, 10–12, 14–16 weeks; Booster: every 1–3 years	Maternal antibodies can interfere with the initial response	(Wang *et al*., 2025)
	Feline Herpesvirus-1 (FHV-1)	Cat	Upper respiratory tract disease	Just like FPV	Routine vaccinations are important for animals that interact with many cats	(Wu *et al*., 2025)
	Feline Calicivirus (FCV)	Cat	Upper respiratory tract disease	Just like FPV	Multivalent reduces the number of injections	(Di Profio *et al*., 2025)
Non-inti (Non-core)	*Leptospira* spp.	Dog	Prevention of leptospirosis in endemic areas	According to environmental risk	Recommended in endemic areas; non-core vaccine	(Sykes *et al*., 2023)
	Bordetella bronchiseptica	Dog and Cat	Prevention of respiratory diseases (CIRD)	According to risk	Especially for animals in kennels or boarding facilities	(Moore *et al*., 2022)
	Borrelia burgdorferi	Dog	Prevention of Lyme disease	According to prevalence area	Booster interval depends on exposure risk	(Malter *et al*., 2022)
	Chlamydia felis	Cat	Prevention of respiratory tract infections	According to risk	Recommended for young cats or cats living in groups	(Ulbert *et al*., 2024)
	Feline leukemia virus (FeLV)	Cat	Prevention of FeLV infection in young cats	According to risk	Important for cats that go outside or come into contact with other cats	(Hartmann *et al*., 2022)

schedule, and the factors that influence the successful formation of immunity (Antipov and Petrovsky, 2025). In addition, advances in modern vaccine technology have opened up new opportunities for improving the efficacy and safety of vaccinations in dogs and cats. Table 2 presents the recommended vaccination protocols for dogs and cats, divided into core vaccines and non-core vaccines.

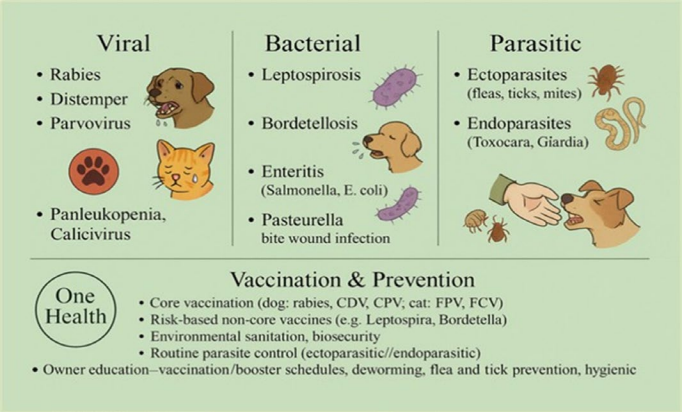

Figure 1. Pet infectious diseases and prevention.

Basic principles of animal immunization

Immunization is a disease prevention measure involving the administration of specific antigens that stimulate the immune system to produce a protective response (Clemente-Suárez *et al*., 2025). In domestic animals, the basic principles of immunization are based on the adaptive mechanisms of the immune system, where vaccines work to stimulate the formation of antibodies and memory cells without causing clinical disease (Song *et al*., 2024). Thus, when animals are exposed to actual pathogens, the immune system is ready to provide a faster and more effective response, thereby preventing severe symptoms or even death (Ahmad *et al*., 2022).

There are two main types of immunization: active and passive (Scotta and Stein, 2023). Active immunization is obtained through vaccination with weakened, inactivated, or modified antigens, which stimulate the formation of long-term immunity (Burghate and Mundada, 2023). Passive immunization is administered in the form of ready-to-use antibodies, such as anti-rabies serum, which provides immediate but temporary protection (Bernard *et al*., 2022). In veterinary clinical practice, active immunization is preferred for long-term prevention programs in pets (Ellis *et al*., 2024).

The principle of immunization also takes into account the age and physiological status of animals (Hofer *et al*., 2022). Newborn puppies and kittens generally acquire passive immunity through their mother's colostrum, mainly in the form of maternal antibodies (Rossi *et al*., 2021). However, these maternal antibodies can interfere with the immune response to vaccines if vaccination is carried out too early (Cinicola *et al*., 2021). Therefore, the initial vaccination schedule usually begins at 6–8 weeks of age with a booster to ensure the formation of optimal active immunity after maternal antibodies decline (Pollard and Bijker, 2021).

The effectiveness of immunization is greatly influenced by individual conditions, including nutritional status, the presence of comorbidities, and exposure to environmental stress (Stuurman *et al*., 2023). Animals with good health status and controlled environments tend to have stronger immune responses than animals with low immunity (Inbaraj *et al*., 2019). In addition, owner compliance with the vaccination schedule plays an important role in ensuring the formation of sustained immunity (Lugelo *et al*., 2022).

By understanding the basic principles of immunization, veterinarians can design vaccination protocols tailored to the specific needs of each individual and population (Chambers *et al*., 2016). This approach not only provides protection for vaccinated animals but also supports the formation of herd immunity, thereby reducing the risk of infectious disease spread within pet communities and to humans (Warimwe *et al*., 2021).

Core vaccines and non-core vaccines in dogs and cats

In pet vaccination protocols, vaccines are divided into two main categories: core vaccines and non-core vaccines (Malter *et al*., 2022). This classification is based on the urgency, prevalence of the disease, and the risk to public health (Zhou *et al*., 2025). Core vaccines are vaccines that must be given to all pets regardless of geographical location or lifestyle, because the diseases they prevent are highly contagious, have high mortality rates, or are potentially zoonotic (Day *et al*., 2010). Conversely, non-core vaccines are given selectively according to exposure risk, environment, and specific animal needs (Malter *et al*., 2022).

In dogs, core vaccines include rabies, canine distemper virus (CDV), canine parvovirus (CPV-2), and canine adenovirus type-2 (CAV-2) (Yang *et al*., 2024). Rabies is a global priority due to its zoonotic nature and fatality rate of nearly 100%. CDV is a multisystem disease with high morbidity and mortality rates, while CPV-2 causes severe, highly contagious gastroenteritis, especially in puppies (Kumar *et al*., 2023). CAV-2 is administered to prevent infectious hepatitis and upper respiratory tract infections (Bru *et al*., 2010). Core vaccine combinations for dogs are generally available in multivalent form, facilitating field application (Aida *et al*., 2021).

In cats, core vaccines include feline panleukopenia virus (FPV), feline herpesvirus-1 (FHV-1), feline calicivirus (FCV), and rabies (Luo *et al*., 2024). FPV causes fatal panleukopenia, especially in kittens (Pacini *et al*., 2023). FHV-1 and FCV are the main agents of highly contagious upper respiratory tract diseases that often cause chronic cases (Henzel *et al*., 2012). Meanwhile, rabies in cats, although less common than in dogs, remains a serious threat in the context of zoonosis (Li *et al*., 2024).

Non-core vaccines in dogs are administered according to specific risks, such as Leptospira spp. vaccines for leptospirosis-endemic areas, *Bordetella bronchiseptica* vaccines for dogs frequently in kennels or boarding facilities, and Borrelia burgdorferi vaccines in regions with high Lyme disease prevalence (Malter *et al*., 2022; Moore *et al*., 2022). In cats, non-core vaccines include *Chlamydia felis*, *Bordetella bronchiseptica*, and feline leukemia virus (FeLV) vaccines, which are recommended for young cats or cats at high risk of living in groups outdoors (Hartmann *et al*., 2023).

Vaccination schedule

Determining the vaccination schedule for pets is a crucial component in ensuring optimal and sustained immunity (Ellis *et al*., 2022). In puppies and kittens, the immune system is still developing, and some immunity is obtained from maternal antibodies through colostrum (Rossi *et al*., 2021). Therefore, early vaccination must be done at the right time to avoid interference from maternal antibodies while providing effective active protection (Cinicola *et al*., 2021). Generally, early vaccination in puppies and kittens begins at 6–8 weeks of age, with repeat doses every 3–4 weeks until 16 weeks of age or as recommended by the vaccine manufacturer (Squires *et al*., 2024). This strategy ensures that animals receive protection before maternal antibodies decline significantly and before exposure to disease agents in the environment (Langel *et al*., 2022).

After the puppy or kitten stage, vaccination in adult animals focuses on maintaining the immunity that has been established (Hookey *et al*., 2024). In adult dogs and cats that have been fully vaccinated during their puppy or kitten stage, booster doses are usually given every 1–3 years, depending on the type of vaccine and local policy (Squires *et al*., 2024). Core vaccines tend to have long-lasting immunity, so booster intervals can be longer, while non-core vaccines or those given for high-risk diseases may require more frequent boosters (Di Profio *et al*., 2025). Determining these intervals takes into account immunogenicity data, exposure levels in the environment, and animal health regulations in the relevant

region (Matsumoto *et al*., 2024).

Boosters play an important role in prolonging the duration of protection, maintaining protective antibody levels, and preventing the onset of clinical disease (Bar-On *et al*., 2021). Without proper boosters, animals may experience a decline in immune response, increasing the risk of infection despite previous vaccination (Lynn *et al*., 2022). In addition, the implementation of a systematic vaccination schedule also supports the formation of herd immunity, thereby reducing the potential for disease spread in pet populations and the risk of zoonosis to humans (Carpenter *et al*., 2022).

Modern veterinary clinical practice emphasizes an individualized approach to determining vaccination schedules (Warman *et al*., 2023). Factors such as age, health status, vaccination history, environmental conditions, lifestyle, and specific exposure risks must be taken into account to develop an optimal schedule (Campling *et al*., 2023). This approach ensures that each animal receives adequate protection with maximum efficiency, while minimizing the risk of side effects from vaccination (Charlier *et al*., 2022).

Factors affecting vaccination effectiveness

The effectiveness of vaccination in pets is influenced by various biological, environmental, and management factors, which can affect the immune system's ability to produce a protective response (Alagawany *et al*., 2021). Understanding these factors is important to ensure the success of vaccination programs and optimal protection of animals.

Age is a crucial factor in the immune response to vaccines (Doherty *et al*., 2025). Young animals receive maternal antibodies through colostrum, which can provide temporary protection but also potentially inhibit the active immune response to vaccines when administered too early (Niewiesk, 2014). Therefore, the initial vaccination schedule must be adjusted so that immunization can stimulate the formation of its own antibodies after maternal antibodies decline (Saso and Kampmann, 2025). Conversely, in adult or elderly animals, the immune system tends to undergo functional changes, such as a decrease in T cell response capacity and antibody production, which may require adjustments in vaccine type or booster intervals (Garnica *et al*., 2022).

The immune response to vaccines is greatly influenced by an individual's immune status (Shao *et al*., 2021). Animals with primary immune disorders, chronic diseases, or severe stress tend to show a lower immune response, so the protection formed may not be optimal (Lynn *et al*., 2022). Nutrition also plays an important role; deficiencies in vitamins, minerals, or protein can reduce the body's ability to produce antibodies and memory cells (Kiani *et al*., 2022). Monitoring health conditions prior to vaccination is highly recommended to ensure a maximal immune response (Montgomery and Larbi, 2025).

The environment in which animals are kept also affects the effectiveness of vaccination (Endale *et al*., 2022). High animal density, poor sanitation, exposure to stress, or extreme climatic conditions can increase the risk of infection while suppressing the immune response (Niu *et al*., 2022). For example, animals that are frequently outdoors with the possibility of direct contact with pathogens have a high risk of exposure, so vaccination must be optimized in terms of both vaccine type and booster interval (Endale *et al*., 2022). Additionally, clean environmental management, good ventilation, and parasite control help support a more effective immune response (Alruwaili *et al*., 2023).

Recent vaccine developments (e.g., recombinant, mRNA, multivalent vaccines)

Vaccine technology for companion animals has advanced significantly in recent decades, offering safer, more effective, and more specific alternatives to conventional vaccines (Si *et al*., 2024). Modern vaccines are designed to stimulate an optimal immune response while minimizing the risk of side effects, thereby supporting more flexible and adaptive vaccination protocols tailored to the individual conditions of the animal (Saleh *et al*., 2025).

One major innovation is recombinant vaccines, in which genes encoding specific antigens from pathogens are expressed in non-pathogenic vector systems or host cells, producing antigens that can stimulate an immune response without causing infection (de Pinho Favaro *et al*., 2022). The advantages of recombinant vaccines include high safety, the ability to differentiate between vaccinated and infected animals (DIVA – Differentiating Infected from Vaccinated Animals), and better stability in storage (Fanelli *et al*., 2022). These vaccines have been widely used for diseases such as rabies, distemper, and panleukopenia in companion animals (Kasondra *et al*., 2023).

mRNA vaccines are the latest approach that offers great potential in animal immunization (Le *et al*., 2022). This technology uses mRNA molecules that encode pathogen antigen proteins, which are then translated by host cells to stimulate humoral and cellular immune responses (You *et al*., 2023). mRNA vaccines have the advantages of rapid development against new pathogens, antigen design flexibility, and the potential for long-term immunity induction (Chen *et al*., 2022). In addition, mRNA vaccines do not use live pathogens, making them safer for animals with weak immune systems (Pardi and Krammer, 2024).

Furthermore, multivalent vaccines are an important innovation for vaccination efficiency (Sanyal, 2022). This type of vaccine combines several antigens from various diseases in one formulation, thereby reducing the number of injections and increasing pet owners' compliance with the vaccination schedule (Hartmann *et al*., 2022). Multivalent vaccines also support simultaneous protection against diseases that often occur together, such as distemper, parvovirus, and adenovirus in dogs, or panleukopenia, herpesvirus, and calicivirus in cats (Abdelhameed *et al*., 2025). As shown in Figure 2, core vaccines for dogs and cats are universal, while non-core vaccines are risk-based with schedules shaped by age, maternal antibodies, and owner compliance.

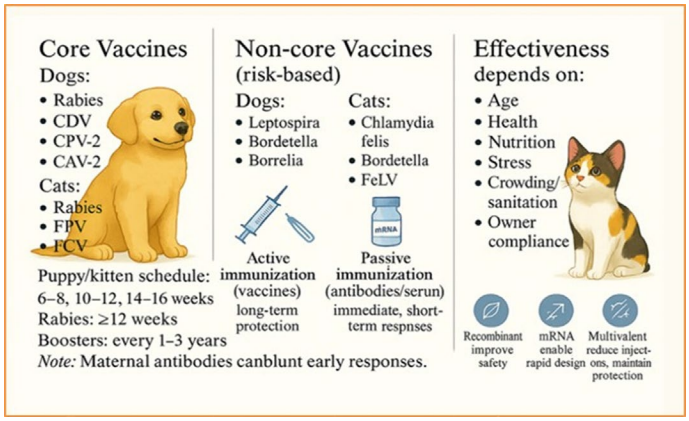

Figure 2. Core and non-core pet vaccines, schedule, and effectiveness.

Non-vaccination prevention strategies

In addition to vaccination, disease prevention efforts in pets also require the implementation of comprehensive non-vaccination strategies (Mshelbwala *et al*., 2024). This approach includes environmental management, biosecurity, parasite control, nutritional and immune maintenance, and pet owner education (Evason *et al*., 2021). By integrating these measures, the risk of infection can be significantly minimized, thereby optimally maintaining the health and welfare of pets.

Environmental management and cage hygiene

Environmental management and cage hygiene are crucial components in the prevention of diseases in pets (Stull *et al*., 2013). A hygien-

ic environment can reduce the pathogen load, inhibit the life cycle of parasites, and lower the risk of transmitting infectious diseases between animals and to humans (Hopkins *et al*., 2022). Housing hygiene includes routine cleaning of feces, food scraps, and drinking water, as well as disinfection of surfaces that frequently come into contact with animals (Penakalapati *et al*., 2017). Maintaining good ventilation and humidity control is also important to prevent the proliferation of pathogenic microorganisms and reduce thermal stress on animals (Guarnieri *et al*., 2023).

In addition, the density of animals in the cage plays an important role (Kurniawan *et al*., 2025). High density increases the risk of direct and indirect contact between animals, thereby facilitating the transmission of infectious diseases (Esposito *et al*., 2023). Proper management practices include limiting the number of animals according to pen capacity, separating sick or newly introduced animals from the healthy population, and rotating play and rest areas to prevent pathogen accumulation (Delsart *et al*., 2020).

The implementation of good environmental management also supports the success of vaccination and other health interventions (Decouttere *et al*., 2021). Animals living in clean and controlled environments have lower stress levels and a more optimal immune status, thereby increasing their response to vaccination and therapy (Li *et al*., 2023). Therefore, environmental management and cage cleanliness are not merely hygienic measures, but integral preventive strategies in maintaining pet health and reducing the risk of zoonotic diseases (Hasan *et al*., 2025).

Biosecurity in clinics and animal shelters

Biosecurity is a fundamental principle in preventing the entry and spread of disease agents in animal environments, especially in facilities that house large numbers of individuals, such as veterinary clinics, shelters, and animal boarding facilities (Verzhykhovskyi and Nedosekov, 2024). Effective implementation of biosecurity involves a series of physical, procedural, and managerial preventive measures to reduce the risk of cross-contamination between animals and between animals and humans (Singh *et al*., 2024).

Biosecurity measures include isolating new or sick animals before introducing them into the general population, using controlled access routes for humans and animals, and separating areas based on disease risk (Clemmons *et al*., 2021). Routine disinfection of equipment, surfaces, and the surrounding environment is an important part of this protocol, in order to eliminate pathogens that can survive on surfaces or in the environment (Assadian *et al*., 2021). In addition, the use of personal protective equipment (PPE) by staff, strict hand washing procedures, and proper management of biological waste are preventive measures that support the success of biosecurity (Cornish *et al*., 2021).

The implementation of biosecurity not only reduces the risk of infectious disease transmission between animals but also lowers the potential for zoonosis among staff and animal owners (Nyokabi *et al*., 2024). In addition, good biosecurity strengthens the effectiveness of vaccination programs and other health interventions, as it reduces the pressure of infection that can lower the immune response (Jimenez *et al*., 2023). Biosecurity principles must be applied consistently and continuously, tailored to the characteristics of the facility, the type of animals housed, and the prevalence of disease in the local area (Huber *et al*., 2022).

Antiparasitic administration and ectoparasite prevention

Parasite control is an important aspect of maintaining pet health and preventing the transmission of zoonoses (Giannelli *et al*., 2024). Ectoparasites such as fleas (*Ctenocephalides felis*), ticks (Rhipicephalus sanguineus), and mites not only cause irritation and allergic dermatitis in animals but can also serve as vectors for various pathogens, including Bartonella spp., Babesia spp., and tapeworms such as *Dipylidium caninum* (Kumar *et al*., 2023). Therefore, controlling external parasites through the administration of modern antiparasitic drugs is a crucial preventive strategy (Rigos *et al*., 2024).

Antiparasitic administration can be done topically, orally, or by injection, depending on the type of parasite and exposure risk (Man *et al*., 2022). Modern antiparasitic products are often broad-spectrum and have a long residual effect, thereby reducing the frequency of application and increasing animal owner compliance (Roeber and Webster, 2021). Additionally, routine administration of antiparasitic drugs according to the recommended schedule can break the parasite life cycle, reduce infestation in animal populations, and decrease environmental contamination (Rigos *et al*., 2024).

Prevention of ectoparasites is not limited to administering medication, but also involves environmental management (Wells and Collins, 2022). Cleanliness of the animal living area, maintenance of dry and clean cages, and vector control in the surrounding environment play a significant role in reducing infestation rates (Wilson *et al*., 2020). Educating pet owners about identifying signs of infestation, antiparasitic administration schedules, and the importance of environmental cleaning is an integral part of this strategy (Sherlock *et al*., 2023).

Nutrition, immunity, and general health

Pet health is greatly influenced by nutritional status, which plays a direct role in shaping and maintaining immune system function (Munteanu and Schwartz, 2022). Adequate nutrition provides the energy and essential macronutrients and micronutrients needed for antibody synthesis, immune cell proliferation, and effective inflammatory responses (Alghamdi *et al*., 2022). Deficiencies in protein, vitamins (especially A, D, and E), and minerals such as zinc and selenium can reduce an animal's ability to fight infection and respond to vaccination, thereby increasing susceptibility to infectious diseases (Stefanache *et al*., 2023).

In addition to nutritional aspects, general health maintenance also includes routine monitoring of the animal's physical condition, early detection of disease, and stress management (Ponnampalam *et al*., 2022). Animals experiencing chronic stress or poor health show a decrease in immune response, which affects the effectiveness of vaccination and susceptibility to infection (Inbaraj *et al*., 2019). General health practices include periodic clinical examinations, dental cleaning, skin and coat care, and weight control. These efforts not only improve animal welfare but also support optimal immune function, thereby strengthening protection against infectious diseases (Alotiby, 2024).

Owner education is an integral component of maintaining nutrition and general health (Alvarez *et al*., 2023). Owners need to be provided with information on balanced feeding, antiparasitic medication schedules, the importance of routine health checks, and early signs of disease (Massetti *et al*., 2023). The level of owner compliance with these guidelines plays a significant role in the success of comprehensive disease prevention strategies (Eschle *et al*., 2020).

Pet owner education

Pet owner education is a fundamental aspect of the success of disease prevention programs in companion animals (do Vale *et al*., 2021). Owners' knowledge and awareness play a direct role in compliance with vaccination schedules, administration of antiparasitic drugs, maintenance of environmental hygiene, and fulfillment of animal nutritional needs (Lopes *et al*., 2022). Owners who understand animal health principles and zoonotic risks are more likely to consistently implement preventive measures, thereby reducing the incidence of infectious diseases and health complications (Ngwa *et al*., 2025).

Owner education includes providing information on early clinical signs of disease, the importance of routine health checks, how to prevent parasitic infections, and managing animal stress and nutrition (Bahk *et al*.,

2018). This approach not only improves animal welfare but also reduces the risk of human exposure to zoonotic pathogens (Liguori *et al*., 2023). In addition, effective education encourages owners to report changes in animal behavior or health conditions quickly, so that medical intervention can be carried out earlier and the risk of complications minimized (Meers *et al*., 2022).

Educational strategies can be implemented through clinical consultations, printed or digital materials, and community outreach programs involving pet owner groups (Powell *et al*., 2022). The use of information technology, such as mobile applications for vaccination reminders and routine health checks, has also been shown to increase owner compliance (Buja *et al*., 2023). By equipping pet owners with the right information, disease prevention efforts can be more effective and sustainable (Sharan *et al*., 2023). As illustrated in Figure 3, the integration of environmental hygiene, biosecurity, parasite control, nutritional and immune support, and owner education substantially reduces infection risk and supports optimal health and welfare in companion animals.

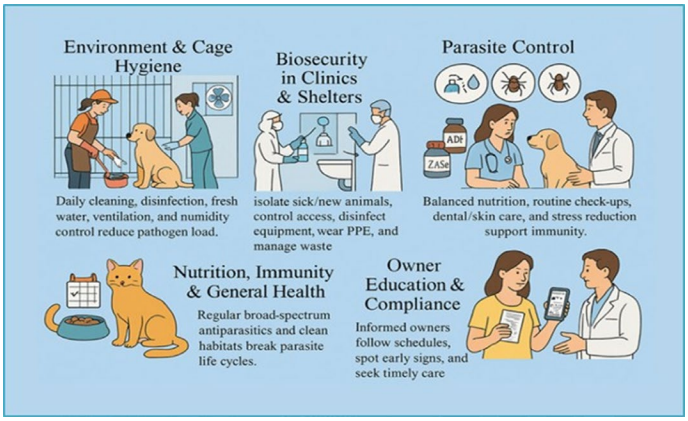

Figure 3. Non-vaccination disease prevention in pets.

Current challenges and issues

Although vaccination protocols and disease prevention strategies for pets have proven effective, a number of contemporary challenges and issues still affect their successful implementation (Carpenter *et al*., 2022). One of the main challenges is owner compliance with vaccination schedules (Okata and Al-Hassan, 2023). Data show that owners often delay or skip vaccinations due to a lack of understanding about the importance of immunization or logistical constraints (Schwedinger *et al*., 2021). Low compliance can reduce immunization coverage, weaken population immunity, and increase the risk of infectious disease outbreaks (Hamson *et al*., 2023).

Vaccine side effects are also a concern, although serious events are relatively rare (Nuwarda *et al*., 2022). Local reactions such as pain or swelling at the injection site, mild fever, and temporary lethargy are the most commonly reported effects (Dighriri *et al*., 2022). More serious side effects, such as anaphylaxis, require immediate medical attention (Dodd *et al*., 2021). Veterinarians' understanding of the safety profile of each vaccine and educating owners about possible side effects are key to minimizing risks and maintaining confidence in vaccination programs (Haeder, 2025).

In addition, the emergence of resistance or variation of pathogens to certain vaccines is an important issue (Frost *et al*., 2023). Virus mutations, new strains, or changes in disease epidemiology can reduce the effectiveness of previously proven vaccines, requiring periodic evaluation of vaccination protocols and adjustment of vaccines used in accordance with the latest scientific data (Excler *et al*., 2021).

Regulatory gaps in vaccination between countries or regions also affect the implementation of vaccination protocols (Mardini *et al*., 2024). Differences in standards, types of vaccines available, and mandatory vaccination policies can lead to inconsistencies in the protection of pets and the potential spread of diseases across regions (Haeder, 2023). Harmonization of regulations and adoption of international guidelines can help improve the uniformity and effectiveness of vaccination (Sajjadi *et al*., 2024).

Advances in digital technology, such as vaccination reminder apps, telemedicine, and electronic health records, offer practical solutions to improve owner compliance (Mc Kenna *et al*., 2023). The use of this technology enables real-time monitoring of vaccination schedules, automatic reminders, and access to educational information about animal health, thereby supporting the implementation of more effective and sustainable disease prevention protocols (Pavia *et al*., 2024).

Future outlook

The development of pet vaccination is predicted to be increasingly influenced by technological innovation and risk-based approaches, in line with the One Health principle (Brun, 2016). New-generation vaccines, including DNA, mRNA, and virus vector-based vaccines, offer great potential in improving the safety, specificity, and effectiveness of immunization (Rezaei and Nazari, 2022). This technology enables more precise antigen design, faster and stronger immune responses, and the ability to develop vaccines against new or mutant pathogens more quickly than conventional vaccines (Lu *et al*., 2024).

In addition, the integration of animal vaccination with the One Health program is an important focus for the future (Entrican and Francis, 2022). This approach emphasizes cross-sector collaboration between veterinarians, medical personnel, animal owners, and public health agencies to control zoonotic infectious diseases (Kurniawan *et al*., 2025). Such integration enables more comprehensive epidemiological monitoring, disease control in animals as a preventive measure for humans, and optimization of health resource distribution (Singh *et al*., 2024).

A personalized approach to vaccination is also an innovative strategy with the potential for widespread implementation (Montin *et al*., 2024). Vaccination personalization takes into account individual animal factors, such as age, immune status, lifestyle, and local disease risk, so that vaccination protocols can be tailored to maximize protection while minimizing unnecessary interventions (Abdaal *et al*., 2024). This strategy supports efficient vaccine use, increased protection effectiveness, and reduced risk of side effects, providing an optimal balance between animal health and population safety.

Conclusion

Vaccination protocols and disease prevention strategies for companion animals are key interventions in maintaining individual and population health, while reducing the risk of zoonoses. Core and non-core vaccinations, combined with non-vaccination prevention practices including environmental management, biosecurity, parasite control, nutrition, and owner education, provide comprehensive protection that improves animal welfare. Implementing evidence-based protocols tailored to specific animal risks supports long-term effectiveness, while modern vaccine innovations and One Health approaches open opportunities for more adaptive and sustainable disease control.

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Conflict of interest

The authors declare that there is no conflict of interest.

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