

**A SYSTEMATIC REVIEW OF FLEA & TICK PREVENTION
COMPLIANCE IN THE CONTINENTAL UNITED STATES**

An Undergraduate Research Scholars Thesis

by

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This project did not require approval from the Texas A&M University Research Compliance & Biosafety office.

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ABSTRACT

A Systematic Review of Flea & Tick Prevention Compliance in the Continental United States

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The purpose of our systematic literature review of ectoparasite prevention compliance is to uncover the percentages of the public who do not comply with the recommended dosage of these drugs and what influences their decisions. With many zoonotic and vector borne diseases prevented by these prophylactic treatments, it is important for both human and animal health to take preventative actions. Our goal is to uncover knowledge gaps in the literature for reasons pet owners do not adhere to drug dosage frequencies, so that veterinarians can properly advocate for patient care in a way that addresses these barriers. By employing key word searches of PubMed and Google Scholar, we documented screened articles in Covidence for a two-person review to identify articles meeting inclusion criteria. Each study had to be geographically in the US, more recent than 1990, and discuss oral or topical (for feline) drugs. Seven articles were included in this review.

Once analyzed, key themes were drawn out of the papers and gaps in knowledge were identified. A major health concern noted by our review is the large percentage of the general public who do not adhere to dosing timelines. The mean percentage of dog owners giving

ectoparasite prevention for a full calendar year ranged from $24.5\% \pm 9.9$ (SE) to $27.3\% \pm 9.1$ (SE). The mean percentage of cat owners giving ectoparasite prevention for a full calendar year ranged from $9.1\% \pm 8.9$ (SE) to $12.2\% \pm 5.7$ (SE). The longevity of medications used, quantity of doses purchased, and lack of owner education were all identified as key influences on the rate of non-compliance and adherence to veterinary recommendations. By targeting these areas for education, products and services provided, veterinarians can improve their clients' compliance and help protect patients from disease. Important gaps in literature knowledge identified included disparities between canine and feline preventative use and research, connection between statistics of non-compliance and causes, a lack of available geographic data for analysis, and the coverage of ectoparasite prevention compared to other preventative medication.

DEDICATION

To the legacy of the Biomedical Research Certificate Program which molded and inspired a generation of Biomedical Scientists at Texas A&M University.

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Contributors

We thank our faculty advisor, Dr. Hamer, for his support throughout this research. We would not have been able to assemble this project without his guidance.

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All other work conducted for the thesis was completed by the students independently.

NOMENCLATURE

Compliance- to be defined as cat/dog owners following veterinary recommendations and administering flea and tick preventatives in a manner that provides year-round protection for their pets.

Non-Compliance- to be defined as cat/dog owners not following veterinary recommendations to administer flea and tick preventatives all year, resulting in less than full year-round coverage for their pets.

Adherence- to be defined as following the recommended administration methods and schedule of flea and tick preventatives providing full, year-round coverage.

1. INTRODUCTION

1.1 Introduction

Pet ownership comes with serious responsibility. This responsibility was highlighted during the recent COVID-19 pandemic and subsequent lockdown as pet owners spent more time at home taking care of their animals. When analyzing pet ownership trends, the American Pet Product Association found that owning a pet resulted in challenges with finding veterinary care, the cost of services, pet behavioral issues, and disruptions during the workday.¹ Furthermore, in a national poll, young individuals and those with children were more likely to adopt during the pandemic, specifically those between the ages of 18-34 years.¹ However, the responsibility and cost of owning a pet during a national lockdown did affect shelters and strain the animal human bond as shelter intakes slowed during the course of the pandemic, and rehoming rates during this time seem to be higher than in typical economic periods.¹

Despite these hardships, pet ownership increased during the pandemic. Internet searches for cat and dog adoptions in google increased by 250% at the beginning of the lockdown.² With changes in business operations due to exposure restrictions, shelters found their procedures changing leading to an overall decrease in animal intake, and a decrease in owner relinquishments as well.³ With such a change in pet ownership during this time with lower shelter intake, higher rehoming, and a younger class of pet owners, access to veterinary care has become more important than ever before. Ensuring this new generation of pet owners understand the basic care and preventatives to use to protect their animal's health is an important topic to be discussed by the veterinary industry at this time.

Veterinary access in the United States, however, is not uniform. Many areas are underserved, and the cost of veterinary care continues to rise. Within the lowest quartile of access to veterinary care, more than 21 million households holding approximately 25.2 million companion animals are found.⁴ When this is considered with the barriers that exist in veterinary medicine, it is shown that many pets are underserved. Surveys done by the Access to Veterinary Care Coalition at the University of Tennessee have shown that household income has an inverse relationship with the odds of facing a barrier to veterinary care, with the number one barrier to care encountered being cost.⁵ Cost has been found to be a barrier to 80% of preventative care of pets.⁵ This preventative care is crucial to reducing the risk of disease and enhancing the longevity of a companion animal. Some of the most prominent diseases that can be eliminated through routine preventative care are vector-borne diseases.

Of these vector-borne diseases, many in the United States are transmitted by fleas and ticks. These arthropod ectoparasites are a nuisance to both household pets and their owners from bites to home infestations. For the proper management of ectoparasite infestations preventative medications exist, but proper time must be made for veterinarians to consult their clients during appointments to discuss the importance and proper usage of ectoparasite preventative medications in order for clients to be aware of these medications.⁶ Without these educational conversations, many clients are left with a misunderstanding of how ectoparasite preventatives should be used and administered and pets are left unprotected.

1.1.1 Drugs

These oral ectoparasite preventatives are parasiticides in the drug class of isoxazoline. They were developed as preventative measures to protect domesticated household pets from fleas and ticks. One of the popular brands of medications on the market is Nexgard; this medication

uses the drug afoxolaner. This drug is noted to be highly effective in literature when given at a 2.5mg/kg dose orally to eliminate both fleas and ticks by blocking insect chloride channels that are ligand-gated with a GABA neurotransmitter.⁷ Similarly, Bravecto, containing fluralaner, is sold across the nation as a three-month flea and tick prevention medication instead of the traditional monthly tablet. Fluralaner provides protection from fleas and ticks for up to 3 months.⁸ Lastly, the veterinary pharmaceutical company Zoetis also markets Simparica as an effective flea and tick prevention. After a thorough screen to produce only S-enantiomer of the drug, a dose of 1.25 to 5 mg/kg of Simparica's sarolaner is shown to be effective at a 99% range.⁹ Sarolaner follows the isoxazoline drug class by inhibiting GABA channels.⁹

1.1.2 Side Effects

While drugs in the isoxazoline class have been extensively researched and proven effective, adverse effects have been seen in some animals. In a recent survey sent to veterinarians and dog owners by Project Jake to later become public record with 2751 survey respondents, 66% of respondents reported adverse effects from their isoxazoline administration.¹⁰ In 2018, the FDA and EMA have listed mild label side effects such as vomiting, decreased appetite, and diarrhea, and some of the isoxazoline drugs have a more serious caution or warning label about seizures or ataxia.¹⁰ The FDA adverse reaction reporting also shows 32,374 reports with 801 deaths and 1728 seizures amid other concerns such as vomiting, itching, and behavioral changes.¹⁰ In the survey by Project Jake, a FDA report, and an EMA reports, Nexgard's afoxolaner was the most common drug given to pets.¹⁰ While each report showed comparable numbers of adverse events, EMA reported 7 to 10 times higher number of seizures or death than the FDA report.¹⁰ These records show the possibility for species toxicity and neurological symptoms by afoxolaner and its isoxazoline drug class.¹⁰

Case studies have also been published regarding seizures, neurologic effects, and death by an isoxazoline drug. In 2019 a 7-month-old Kooikerhondje dog began experiencing myoclonic jerks, ataxia, tremors, and more neurological effects 24 hours after a dose of Bravecto.¹¹ The case study showed the puppy to be diagnosed with impaired vestibular-cerebellar functions, which resolved itself about 11 hours after presentation without treatment.¹¹ With the known pharmacokinetics of such a drug, blocking chloride channels in this puppy's central nervous system is suspected for the presentation of transient ataxia.¹¹ With case studies, adverse events surveys, and public surveys such as the one by Project Jake, with a quick google search owners may become weary of these medications and their safety.

Another unintentional side effect of ectoparasite prevention stems from the improper administration of medication formulated for dogs to cats. Permethrin spot-on (PSO) toxicity is caused when canine topical ectoparasite prevention containing a type 1 pyrethroid called permethrin is administered to a cat.¹² Cats are especially susceptible to permethrin and can develop PSO toxicity which can manifest as muscle tremors and seizures that either resolve with treatment or progress to death.¹² One study found that 81% of veterinarians that responded to a survey reported that they had seen PSO toxicity in the previous two years.¹² Of the total 705 PSO toxicity cases reported, 22% or 166 cases resulted in the death of the patient.¹² With increased client education, access to information on the dangers of permethrin containing topical products, and decreased non-veterinary retailers, the amount of PSO toxicities from improper use of ectoparasite prevention can be decreased.¹² With cases of neurologic adverse reactions seen in both dogs and cats to different medications in this drug class, it is important for veterinarians to reassure their clients of the safety and efficacy of these medication. When looking at the possible symptoms of diseases transmitted by the parasites these drugs prevent in comparison to the rare

adverse reactions recorded, the importance of these drugs from a public health standpoint is shown.

1.1.3 Disease

The most common flea causing problems for domesticated indoor pets in the US is the cat flea (*Ctenocephalides felis*). However, there are many other fleas that can cause issues across the United States such as the dog flea (*Ctenocephalides canis*); *Pulex simulans*; *Xenopsylla cheopis*, the oriental rat flea; *Pulex irritans*, the human flea; and the *Nosopsyllus fasciatus*, or the Northern Rat Flea.¹³ Direct harm caused by flea feeding includes flea allergic dermatitis, where flea bites and the delivery of salivary proteins cause itchiness, hair loss, scabs, and more.¹³ Fleas can also transmit agents of disease to dogs and cats, the most common being *Dipylidium caninum* or the tapeworm.¹³ Subcutaneous infections of nematode *Acanthocheilonema reconditum* in dogs has been attributed to fleas, and Tungiasis from fleas can cause an inflammatory skin response as well.¹³ Beyond transmitting parasites, Fleas can also transmit bacteria such as *Rickettsia* spp., flea-borne spotted fever, Murine Typhus, Bartonella which can cause flu-like symptoms in those infected whether animal or human, and can transmit the infamous Cat Scratch Disease.¹³ With such a wide array of possible diseases transmitted to both dogs and cats by fleas, their management should become a priority. Especially given 80% of fleas removed from cats contain an agent of disease that threatens cat or human health.¹⁴

Tick populations vary across the climate and coasts of the United States, and much like fleas can deliver a wide array of diseases to domesticated companion animals. When traveling outdoors, dogs can encounter infected ticks. One protozoa transmitted by ticks to dogs is *Babesia canis*, causing Babesiosis, a potentially deadly disease involving anemia and organ complications whose severity depends on the protozoa species transmitted.¹⁵ If an infected tick is

ingested, the protozoan responsible for Canine hepatozoonosis can be transferred to a dog infecting leukocytes and causing complications with co-infections of other tick-borne diseases.¹⁵ Beyond these protozoa, ticks also transmit bacteria such as *Ehrlichia* which can cause canine ehrlichiosis and a destruction of platelets and splenic sequestration.¹⁵ Several species of *Borrelia* bacteria are also transmitted by ticks, the most common being *Borrelia burgdorferi*, the agent of Lyme disease.¹⁵ Lastly, ticks transmit multiple species of *Rickettsia*, one of which causes Rocky Mountain Spotted Fever which can be fatal in dogs.¹⁵ With such a wide array of diseases transmitted by both fleas and ticks there is an increased importance for veterinarians to continue their education and participate as experts to help manage vector-borne diseases to protect animal and human health in areas with increased vector-borne disease.¹⁶

1.1.4 Compliance

With so many direct and indirect problems associated with fleas and ticks, effective preventative oral or spot-on feline medications given a few times per year are a crucial step in prevention. However, similarly to antibiotics and other medications, compliance by owners for this medication is low. In a preliminary report done by Merck in 2021, 506,637 dog records were analyzed from over 600 hospitals showing only 43% of owners purchased flea and tick prevention.¹⁷ While this number is low, the compliance is lower. 31-65% of owners had a gap in their schedule depending on the drug itself, causing Nexgard's afoxolaner only being effective 40% of the year, Bravecto's fluralaner 65% of the year, and Simperica's sarolaner being effective 30% of the year.¹⁷ This issue with compliance is not bound to the United States. In Portugal, a study done in Lisbon University showed out of the 312 patients surveyed visiting the hospital 28.4% of dogs were given an ectoparasite protection without any gaps, and in terms of disease prevention 85% of clients did not know the meaning of the term "zoonosis".⁶ These

inconsistencies with ectoparasite prevention administration and the lack of knowledge of preventable diseases reinforce the importance of the veterinarian-client relationship for accurate education and guidance.

1.2 Objective

The purpose of our systematic review is to determine the percentage of pet owners in the continental United States who do not adhere to the 12-month dosage recommendation of ectoparasite preventatives. By determining the percentage of owners who are non-compliant with these medications, we hope to uncover any contentions in the literature that will explain these owner's decisions and reasons they choose to leave their pets unprotected throughout the calendar year. This will also allow for any gaps in knowledge in the literature to be seen to help researchers and veterinarians work together to mitigate any hidden misconceptions in administration and compliance the public may hold. This will enable veterinarians to advocate for proper preventative care and adjust their arguments to refute common misconceptions the public may hold about medication, improving public health for both their patients and clients as well.

2. METHODS

2.1 Literature Review

Using keyword searches in PubMed and Google Scholar, peer-reviewed publications were collected determining the compliance and adherence of the public to the appropriate usages and durations of ectoparasite preventative medications as recommended by both veterinarians and manufacturers. Key words searched included “flea and tick preventative compliance,” “flea and tick owner compliance,” and “ectoparasite compliance.”

Inclusion criteria included 1) evaluation of oral or spot-on formulations of ectoparasite preventatives, 2) provide quantitative data about compliance and or adherence to ectoparasite preventative use 3) study was conducted in the United States, and 4) published between 1990 to 2022. Exclusion criteria included 1) review articles, 2) studies of repellent or insecticidal collars, and 3) introduction studies which surveyed pet owners of their frequency of administration before and after the introduction of a different medication. Once an article met inclusion criteria, it was embedded into a Covidence screen. Through a two-person review, each article’s abstract was approved by each member of this team for entry into this review to minimize reviewer bias. Once approved to have passed all exclusion criteria by both authors independently, data was extracted from each article regarding products and drugs evaluated, time of data collection, percentages of compliance reported by owners, and reasons for lack of adherence to dosage schedules. The percentages of owners compliant with full year recommended coverage from each paper were taken to compile a mean average of compliance for both dogs and cats with standard error using Microsoft Excel functions.

3. RESULTS

3.1 Article Summaries

The systematic literature review yielded 5,847 articles that resulted from keyword searches, 7 of which met inclusion criteria. The mean percentage of dog owners giving ectoparasite prevention for a full calendar year ranged from $24.5\% \pm 9.9$ (SE) to $27.3\% \pm 9.1$ (SE). The mean percentage of cat owners giving ectoparasite prevention for a full calendar year ranged from $9.1\% \pm 8.9$ (SE) to $12.2\% \pm 5.7$ (SE).

3.1.1 *Gates et al 2010*¹⁸

By characterizing the anti-parasitic drugs used on 5276 dogs and 1226 cats that were admitted to the University of Pennsylvania teaching hospital from January 1999 to December 2006 who had suspected endoparasites, prophylactic compliance was recorded. 74% of the canines were noted to have used flea and tick preventatives, and 38% of the cats were on ectoparasite prevention. When asked whether these preventatives were given year-round, respondents indicated 61% of dogs and 47% of cats in the study populations receiving preventatives complied with their suggested year-round schedule. Two associations for an animal to have a statistically significant increase in likelihood of taking prophylactics were being neutered and living in a median household income. April, May, and June were shown to have an increase in preventative usage as well. The authors contend that the decrease in preventative usage after November may be due to company advertisement during Lyme Disease Awareness Month earlier in the year.

3.1.2 *Lavan et al 2017*¹⁹

Over 559 dog owners between 24 veterinary hospitals from the northeast, central, south, and west United States were studied on their compliance. The flea and tick preventive recommendations given to clients were tabulated, as well as follow-ups with dog owners through a compliance survey from April 2016 to June 2016. All owners were receiving fluralaner (Bravecto) from the hospital at the time of the study. With only 62% of clients stating they remembered flea and tick prevention should be given year-round, with most owners thinking personally that their dogs should be protected from these ectoparasites at 73%. Meanwhile only 13% of the owners in this study purchased enough fluralaner from the hospital to provide a full year of coverage, so there is a large disparity shown between belief and action. The author proposed seasonal weather changes, finances, and lack of thought for reasons why compliance was faulty.

3.1.3 *Lavan et al 2018*²⁰

Transaction records from veterinary clinics across the United States were collected from June 2014 through March 2017 to compare canine ectoparasitic administration compliance between extended dosing product, fluralaner (Bravecto), with monthly dose products, afoxolaner (Nexgard) and spinosad (Comfortis). It was discovered that on average owners only purchased enough doses of medication to cover their pet for 6.1 months out of the year. On average, the extended duration protection provided by fluralaner is the highest at 5.7 months of protection compared to 4.6 months by afoxolaner or 3.3 months by spinosad. Overall, it was noted that compliance increased with the use of a longer acting medication than a monthly dose. Additionally, overall months of coverage increased with the purchase of multiple doses with assumed compliance after purchase. The study concluded that increased compliance occurs with

longer duration ectoparasiticide or larger purchase quantities resulting in a longer average ectoparasite coverage over a year.

3.1.4 Simon & Yorty 2019²¹

This study takes place in a “midsized” Pennsylvania veterinary hospital in the fall of 2019. Here when dogs were presented with fleas, their file was analyzed for preventative history. Dog owner surveys were also deployed for preventative history and past purchasing behavior. In the fall, small dogs were statistically more likely to have fleas. 57% of the dogs in the fall who had fleas were not on preventatives. 64% of clients said they would give their dogs flea and tick prevention year-round, while 20% said they refrain from preventatives in the winter. The author contends that the percentage of dogs who were on prevention and still arrived with fleas were using imidacloprid (Seresto collars) or fipronil (Frontline).

3.1.5 Lavan et al 2021²²

Purchase records from 671 veterinary clinics across all regions of the United States from January 2017 through June 2019 were collected to evaluate the presence of gaps and noncompliance in the administration of feline ectoparasiticide preventatives purchased over a year-long period. The feline ectoparasiticides included fluralaner (Bravecto) , fipronil/(S)-methoprene/pyriproxyfen (Frontline), imidacloprid/pyriproxyfen (Advantage), and selamectin (Revolution) as the active ingredients. Most owners purchased less than six months of prevention with between 61-75% buying 1-3 months' worth of prevention. They found that the average gap between dose administrations decreased with an increase in the number of doses purchased. The average gap between doses also decreased with the administration of the longer-acting medication, fluralaner (Bravecto), compared to monthly medications like selamectin (Revolution), fipronil (Frontline), or imidacloprid (Advantage). Cats who received fluralaner

(Bravecto) had twice as long protection proportionally compared to monthly ectoparasiticides. Overall, compliance and protection were maximized with an extended duration dose medication, reduced gaps between purchases, and increased quantity of doses purchased.

3.1.6 *Lavan et al 2021*²³

626 veterinary hospitals in the United States were surveyed to evaluate the compliance of canine owners with the timing of ectoparasite prevention purchase and estimated administration during a 12-month period. Medications included afoxolaner (Nexgard), fluralaner (Bravecto), lotilaner (Credelio), and sarolaner (Simperica). It was found that 43% of owners purchased only one month worth of preventives in the span of a year and gaps between purchases were found for 31-65% of dogs. Fluralaner (Bravecto), an extended duration medication, had the second smallest gap between purchases and the longest aggregate protection period when compared to the other medications. This longer protection period is attributed to the longer period needed between doses provided by the nature of it being a longer duration medication than the monthly options. For the monthly preventatives, the average span of protection increases in correspondence to the number of doses of medication purchased. Interestingly, the longest “dose plus gap” interval for monthly preventative was experienced between the 6th and 7th doses. The authors attributed this to the fact that most preventatives are packaged in 3- or 6-month groupings allowing for an increased delay to repeat purchasing after the 6th dose.

3.1.7 *Lavan et al 2022*²⁴

This study analyzed canine ectoparasiticide purchases from 626 veterinary hospitals throughout the United States to estimate compliance with administration guidelines and find average dose purchase gaps. Across the United States surveys were conducted from January 2017 to December 2019 and included four different medications: afoxolaner (Nexgard),

fluralaner (Bravecto), lotilaner (Credelio), and sarolaner (Simperica). It is noted that compliance is assumed when owners purchase multiple months. Less than 20% of owners purchased 7 to 12 months of prevention and less than 33% purchased 4 to 6 months of prevention despite veterinarian recommendations of year-round prevention. Around 42% of owners who purchased more than one dose of prevention did not fully comply with administration guidelines and allowed time gaps between administration of doses. However, it was found that the average time gap between doses decreased as the number of doses purchased increased. Additionally, it was noted that compliance increased with longer duration medications such as fluralaner (Bravecto) and this phenomenon was tied to simpler, less frequent regimens improving compliance across previous research.

4. CONCLUSION

4.1 Discussion

4.1.1 Non-Compliance

The mean percentage of compliant pet owners giving ectoparasite prevention year-round is drastically lower than expected. Only approximately a quarter of dog owners and a tenth of cat owners across the United States are following veterinary recommendations to give ectoparasite preventatives for 12-month protection. This leaves household pets vulnerable to preventable agents of disease such as *Borrelia burgdorferi* and *Rickettsia* spp. that can then be transmitted to their owners if the flea or tick was brought indoors, posing a major public health concern.

4.1.2 Non-Compliance Factors

When analyzing factors that impact an owner's adherence to recommended ectoparasiticide administration frequency, some reoccurring themes became apparent. Of the seven articles reviewed, 4 cited the duration of medication and quantity of medication purchased at once as key factors to influencing consumer compliance.^{20,22-24} The papers found that owners were more likely to be more compliant with administration timelines when the preventatives had a longer duration and reduced time gaps between dose administration, such as the 12-week preventative fluralaner (Bravecto).^{20,22-24} One paper found cat owners to be twice as likely to be compliant when using the longer lasting fluralaner (Bravecto) at 68% when compared to monthly preventatives at 32-35%.²² Similarly, owners were more likely to be compliant when they purchased multiple doses of preventative at once.^{20,22-24} Another common theme between articles is the influence of the season on preventative uses.^{18,19,21} According to one study in Pennsylvania, owners who don't use preventatives year round are more likely to only use the

during the warmer months of May through November and particularly during the summer.¹⁸ Additional sources went more in depth into the considerations they found important for influencing consumer compliance and adherence. Interestingly, none of the papers in the literature review posited that owners might be wary of using flea and tick preventatives due to fears about side effects. One paper posits that there are three main issues to look at; lack of in depth veterinary discussions with clients, misleading information, and cheaper but often inferior products that don't require a prescription.²⁵ The lack of client education from their veterinarian was mirrored by one of the reviewed articles that found only a small portion of veterinarians had been routinely discussing the importance of parasite prevention with their clients.¹⁸ A survey of owners analyzing the most important factors in their choice of products found that owners were more likely to purchase a ectoparasiticide that has a broader spectrum of action and a lower price for administration.²⁶ Bringing these ideas together, it seems that the key ways to improving pet owner's compliance and adherence to the recommended usage of ectoparasite preventatives are for veterinarians to provide more information to clients about preventatives importance, discuss the benefits of a longer lasting medication, and provide cost-effective broad spectrum medications.

4.1.3 Disparities of Knowledge

While conducting this literature review, a few gaps in the available literature became evident. One major disparity was that studies were far more likely to discuss and focus on canine ectoparasite prevention than feline prevention. Only two out of the seven studies reviewed provided some statistics for feline preventative use and of the two only one provided more analysis than just basic population data.^{18,22} This gap is reflective of the lower use of prophylactic products in feline patients, on average from 9.1% to 12.2% of cats with full year

coverage, compared to canine patients with 24.5% to 27.3% having full year-round coverage on average. While this can partially be attributed to the lower percentage of felines being outdoor pets, this is also reflective of the fact there is a major disparity in veterinary care and research for cats and dogs. This disparity in the care provided for canine and feline patients at veterinary clinics across the US is in literature. In one study not meeting inclusion criteria of this study, found that while 90% of dog owners visited a veterinarian only 40% of cat owners visited a veterinarian at any point in time.²⁷ Targeting this gap in veterinary care will vastly help improve the health and wellbeing of feline patients across the country. Increased research into the causes for lower veterinary attendance and compliance with recommendations is essential to gaining a full understanding of the problem at hand and how to best approach it. Another gap noticed in the research was that most articles that were screened or reviewed focused on either the percentage of non-compliance and only suggested likely causes of non-compliance, not linking both statistically or directly. Tying together the influences on non-compliance and their direct effects on the statistics on non-compliance and adherence is vital to being able to start fixing the issue, not just identifying that there is an issue. A third gap identified in the literature is that papers that went in depth on statistical analysis of preventative use often went more in depth about the use of heartworm preventatives than flea and tick preventatives.¹⁸ This disparity can be improved with an increase in research over the in-depth statistics behind ectoparasite prevention use, adherence, and non-compliance.

4.1.4 Bias

It is important to acknowledge a few key biases that may be present within the reviewed articles. Out of the seven reviewed articles five were by the same author, Dr. Robert Lavan, who works at Merck Animal Health.^{19,20,22,23} Dr. Lavan is a continually active author and researcher

in the field of ectoparasitic prevention and has published the majority of the recent articles we screened. It is of importance to note that Merck is the company that produces fluralaner (Bravecto) which was noted in various studies to be preferred by owners due to the increased time of coverage and had increased percentage of compliance.^{20,22-24} The methodology of the studies should negate most of the bias associated with this as they analyzed more than just their product and objectively looked at purchase records for a large population of clinics to conduct their statistical analysis. A second bias that was mentioned in multiple papers was that in order to complete their statistical analysis of gaps in coverage, it was assumed with the purchase on multiple doses at one time that owners adhered to the regimen of dosing and were not delayed in administering doses.^{20,23,24,28} By assuming that a purchase of prevention means administration on the same day and a larger quantity of purchases means administration on time after the first dose, this bias influences the results of the papers by presenting the “best case scenario” of the smallest possible gaps and non-compliance with their analysis. It is key to note that it is more than likely that compliance and adherence were not continued immediately in a linear fashion after purchase and that actual compliance of owners is lower than concluded.

4.1.5 Future Research

This literature review highlighted a few key areas of flea and tick preventative research and knowledge that need to be improved for a more comprehensive understanding of the compliance of pet owners in the United States to the recommended administration of these drugs. Developing research methods that investigate correlations between quantitative measures of compliance and the factors influencing non-compliance is the next step in this field required to start to reduce the gaps in knowledge. From our search no papers gave exact causes for the owners studied who did not provide ectoparasite prevention coverage for their pets year-round.

The author suggested possible reasons, so without definite causes it is hard for veterinarians to bridge this gap and mitigate the percentage of their non-compliant owners.

One possible project design that could be used to bridge this gap is a national study that interviews veterinarians and surveys pet owners with questions developed in a reflective manner. With the interviews, the veterinarian perspective on what they consider standard of care, direct reasons they encounter every day as to why an owner is not compliant with dosage recommendations, and the veterinarian's current methods for resolving these reasons. With the surveys, a client's perspective on any factors that do or could impact their compliance and adherence can be analyzed in direct relation to the percentage of the year they adhere to veterinarian recommendations. The results collected can then be compared to each other allowing common themes to be identified to reveal definite causes for the low percentage of adherence to these important preventatives we discovered through this review. Additionally, discrepancies between veterinary and client perspectives can be identified and used to enhance both client education and veterinarian communication methods and educational focuses to improve compliance and patient protection.

A second area of expansion for future research is to correlate compliance percentages and influencing factors with temporal and geographical data. Primarily, correlations through this analysis can be used to determine if there are any factors, themes, or discrepancies that are more prevalent in one geographical region compared to another. Presumably, factors that might influence a client in Texas might be different than factors that influence clients in Maine. Therefore, this geographical correlation data can then be used to inform and direct veterinarian and educational efforts to be more effective for a specific target population. Secondly, geographical data and compliance can be compared to incidence maps of common flea and tick-

borne diseases. Resulting data can be used for a variety of purposes such as highlighting areas of higher zoonotic disease risk, educational information for affected veterinarians, or directing areas for future research in flea and tick preventatives. But in order for data like this to be published for a necessary expansion in the field, studies, such as the ones we reviewed and the proposed design above, need to include fairly detailed geographical data connected to the statistics generated. Ideally, specific cities or coordinates would be included with each response in order to be able to conduct a study involving GIS analyses. The overwhelming majority of the articles reviewed for this study did not include precise or narrowing location data, merely a broad finger point at their region in the United States. This negated any geographical analysis we had hoped to do. In order for longitudinal studies to take place, or for flea and tick prevention compliance to be overlaid with incidence maps of diseases such as Lyme disease or Erlichia, more geographical data must be shared in the scientific community when conducting these compliance studies.

A third area of study that would be interesting to expand the research into is the impacts of social demographics of an area on the compliance of flea and tick preventative use. In reality, not every pet owner might be able to afford the cost of monthly flea and tick preventatives on top of other preventative and basic annual wellness care. A deeper understanding of flea and tick preventative use can be gained through the expansion of geographical data in ways that include socioeconomic overlays or specific social and societal concerns. By looking at responses of veterinarians through the context of what population they work in, plans can be developed to specifically target the highest needs and impacts of an area. While factors such as disposable income might be an obvious impact on flea and tick prevention compliance, working to determine the ideal price for increased client purchases while sustaining a profit margin or

developing incentives and bundle deals may help increase pet protection in local areas with differing economic status. Again, in order for these studies that could bridge current knowledge gaps to take place, a more open exchange of geographical data is needed.

4.2 Conclusion

Through the analysis of the 7 articles analyzed in this systematic literature review, a major health crisis occurring in the veterinary health network was identified. On average only 24.5% to 27.3% of canines have year-round ectoparasite protection while only 9.1% to 12.2% of felines have year-round ectoparasite protection. This means that a substantial percentage of clients across the United States are not complying to the recommended year-round ectoparasite administration schedule, and many pets across the nation are left unprotected from these parasites and the pathogens they transmit. Further research should be done to correlate influence of client non-compliance with quantitative non-compliance data, as much of the literature we found either focused on the percentage of a population who did not give ectoparasite prevention while only suggesting general reasons why an individual would not give ectoparasite prevention. Measures to improve ectoparasite compliance could also be aided through research into geographical connections of longitudinal studies or incidence maps of vector borne diseases, as well as social demographic impacts. This further research would allow for veterinarians to have discussions with clients during visits and advocate for patient protection with information guided by research and designed specifically for their region and clientele. However, based on the results of our review by advocating for the importance of flea and tick prevention, discussing the availability of longer-lasting medication, and providing a range of cost-effective medications, veterinarians can help play a role in bridging this disparity in health care and provide a method to raise the standard of health for their canine and feline patients.

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APPENDIX: REVIEW SUMMARY

Table A.1: Review Summary

Study	Sample Size	Date	Species	Drugs	Percentage of Full Year Coverage	Noncompliance Factors
Gates et al 2010	5276 dogs 1226 cats	1999 - 2006	Canine and Feline	Fipronil, imidacloprid, and selamectin	45% Canine 17.9% Feline	Seasonal changes, reproductive status, household income, time of yearly preventatives, and veterinary support
Lavan et al 2017	559 owners	2016	Canine	Fluralaner	13%	Season changes, finances, lack of thought
Lavan et al 2018	231,565 dogs	2014 - 2017	Canine	Spinosad, fluralaner, and afoxolaner	1.7 - 5.6%	Client education, quantity purchased at a time, duration of medication
Simon & Yorty 2019	~30,000 patient	Sept 2018 - Nov 2018	Canine	Afoxolaner, fluralaner, lotilaner, and sarolaner	64%	Season changes
Lavan et al 2021	506,637 dogs	2017 - 2019	Canine	Afoxolaner, fluralaner, lotilaner, and sarolaner	11.6-18.2%*	Quantity purchased at a time and duration of medication
Lavan et al 2021	114, 853 cats	2017 - 2019	Feline	Fluralaner, methoprene, imidacloprid, or selamectin	0.2-6.5%*	Quantity purchased at a time, duration of medication, method of purchase, lack of thought
Lavan et al 2022	506,637 dogs	2017 - 2019	Canine	Afoxolaner, fluralaner, lotilaner, and sarolaner	11.6-18.2%*	Quantity purchased at a time, duration of medication effects, perceived lack of effectiveness

*Indicates paper grouped 7-12 months of coverage into one statistic