AJVR

AVMA

Retrospective observational study shows accelerometers can monitor effects of canine pruritus treatment

Abigail O'Rourke, PhD[1*]; Leah Redford, MS[1]; Aletha Carson, DVM[2]; Scott Lyle, MBA[2]; Cassie Kresnye, PhD[2]; Ciaran O'Flynn, MS[1,3]

[1]Waltham Petcare Science Institute, Waltham on the Wolds, Leicestershire, United Kingdom
[2]Pet Insight Project, At-Home Diagnostics, Mars Science & Diagnostics, New York, NY
[3]Machine Intelligence and Decision Systems Research Group, Queen Mary University of London, London, United Kingdom

*Corresponding author: Dr. O'Rourke (abigail.orourke@effem.com)

OBJECTIVE
To evaluate the use of collar-mounted accelerometers to objectively monitor treatment outcomes in canine pruritus.

METHODS
Observational data from 1,803 dogs from 2019 through 2023 were retrospectively analyzed to evaluate the efficacy of collar-mounted accelerometers to assess treatment efficacy for pruritic canine skin diseases. Accelerometer measurements were joined to electronic health records to establish symptoms, diagnoses, and interventions. A directed acyclic graph was used to identify relevant variables to control for, and linear regression was used to model the pruritic behaviors before and after intervention.

RESULTS
Significant reductions in pruritic behaviors, particularly scratching and licking, were observed following interventions. Antibody and immunosuppressant treatments exhibited the most pronounced effects on scratching behavior, with a reduction in scratching of up to 40.9% and 23.4%, retrospectively, in the 30 days following intervention relative to the 14 days prior.

CONCLUSIONS
Collar-mounted accelerometers used to measure pruritic behaviors can detect the effects of interventions for canine pruritus.

CLINICAL RELEVANCE
Pruritus is a common symptom of canine skin diseases, such as atopic dermatitis or allergic dermatitis, which can be difficult to diagnose and manage. This study highlights the use of collar-mounted accelerometers to objectively monitor treatment outcomes for canine pruritus, providing valuable insights into treatment effectiveness that could allow veterinarians and pet owners to optimize management strategies to alleviate the burden of this challenging condition.

Keywords: dermatitis, accelerometers, canine dermatitis, pruritus, pruritic canine dermatitis

Pruritic skin diseases in canines can present challenges for veterinarians and pet owners alike. Unlike some medical conditions with straightforward diagnostic procedures, identifying and managing the underlying cause of pruritus often demands a multifaceted approach: assessing patient history, observing clinical signs, and conducting tests alongside monitoring the pet's response to administered treatments.[1] Canines exhibiting pruritic behaviors, such as excessive scratching and licking, are frequently treated with a range of interventions, including immunosuppressants, medicated shampoos, antihistamines, antimicrobials, and biologic therapies. These treatments may be initiated empirically, especially when clients may be unable or unwilling to pursue a full diagnostic workup to differentiate between common underlying etiologies.

Monitoring the clinical response to treatment—including instances of nonresponse—is helpful in refining the differential diagnosis and guiding subsequent therapeutic interventions. Reliance on

Received September 24, 2024
Accepted December 4, 2024
Published online January 22, 2025

doi.org/10.2460/ajvr.24.09.0269

subjective reporting of pruritus from pet owners complicates the accurate assessment of treatment efficacy. Chronic skin diseases, such as atopic dermatitis and allergic dermatitis, impose a significant burden not only on the affected animals—due to persistent pruritus, erythema, and discomfort—but also on the pet owners, who must manage frequent veterinary appointments, ongoing medication expenses, and, in some cases, specialized diets.

This study focused on exploring an innovative approach to monitoring interventions for pruritic behavior in canines at a large scale in real-world environments. Objective data on pruritic behavior has the possibility to be leveraged by veterinarians and pet owners to understand and quantify the effectiveness of treatment interventions, potentially fulfilling a longstanding need for improved management strategies in this frustrating condition. Clinical signs of pruritus can be measured accurately using a collar-mounted accelerometer,[2–5] where previous work[3–5] demonstrated assessment of scratching with sensitivities between 76.9% and 87.0% and specificities of 99.7% to 99.8% and self-licking with a sensitivity and specificity of 77.2% and 99.0%, respectively.[5] Measurements of scratching recorded through collar-mounted accelerometers have been shown to agree with those made using an owner-reported visual analog scale.[6] The objective of this investigation was to use retrospective data to determine whether a collar-mounted accelerometer can effectively detect and measure differences in the effects of dermatological interventions in real-world veterinary practice.

Methods

Data

This was a retrospective observational study based on real-world data collected from 2019 through 2023 by the Pet Insight Project,[7] an initiative that distributed 100,000 collar-mounted accelerometers (Whistle FIT; Mars Petcare) to clients of Banfield Pet Hospitals (a network of primary care hospitals operating in over 1,000 locations in 42 US states). All participants provided informed consent to use their dogs' electronic health records (EHRs) records and Whistle data. The data for this study is comprised of EHRs collected from visits concerning dermatological conditions at Banfield Pet Hospitals and measures of pruritic behaviors (licking and scratching) as daily totals derived from a collar-mounted accelerometer. The pruritic behavior measures were determined by FilterNet, a deep learning algorithm that processes accelerometer data and identifies pet behaviors and can classify a self-licking event with a sensitivity (specificity) of 0.772 (0.990) and a scratching event with a sensitivity (specificity) of 0.870 (0.997).[5] These events are then aggregated and presented as trend analyses in the user interface. The data were joined by a unique identifier assigned to participants of the Pet Insight Project. Dogs were included in the study if they had evidence of a dermatological condition within their EHR (recorded as "dermatitis" or "dermatitis, atopic allergic") and had made at least 2 visits to a Banfield Pet Hospital in their lifetime. Recording a diagnosis of "dermatitis" in a dog's EHR often serves as a placeholder for nonspecific skin inflammation, requiring further diagnostics to reach a definitive diagnosis. Visits at which a record of "dermatitis" or "dermatitis, atopic allergic" was made are henceforth referred to as "dermatitis visits." To exclude visits with a historical dermatitis diagnosis, visit records were filtered to only include records where the date of diagnosis matched the visit date. Intervention data were processed from the medical notes and invoices within the EHRs and categorized into antimicrobial, antibody, antihistamine, antiparasitic, immunosuppressant, shampoo, antihistamine, pain medication, and anti-inflammatory **(Supplementary Table S1)**. Visits were tagged with each category of treatment prescribed (ie, a visit could be tagged with multiple categories if combinations of treatments were prescribed). A category was also created for dogs that did not receive an intervention at the time of the visit or within 60 days; this may include dogs that had interventions but were not recorded in the EHR. A record was considered valid if the accelerometer recorded data for at least 12 of 24 hours of the day. Data were imputed for any missing timeframes using a personalized model per dog. For each hour in the day where the dog had data collected for the full hour, the exponentially weighted moving average and variance were calculated and combined with the dog-specific historical data for that day of the week and hour of the day using inverse-variance weighting. Dogs were excluded from the study if they did not have at least 20 valid days of accelerometer records in the 30 days both before and after their dermatitis visit (in total, 60 days were evaluated surrounding the EHR). Given that a dog may have multiple incidences of pruritic skin diseases within its lifetime, a dermatitis visit was selected at random per dog so that each dog only had 1 diagnostic record within the dataset. An additional variable indicating the number of previous dermatitis-related visits for each pet was determined. Following this processing, a dataset, defined as "dataset 1," was composed of daily accelerometer records of the total time spent licking and scratching for the 60 days prior to the EHR and the 60 days following, with the diagnosis and intervention information attached. A subset of dogs with only 1 intervention type within the EHR was defined to allow for the identification of direct effects related to specific interventions, labeled "dataset 2." The data processing steps are summarized in **Figure 1**.

Statistical analysis

Analysis was performed in Python (version 3.9.13, Python Software Foundation) using *pandas* (version 1.3.5)[8] and *statsmodels* (version 0.14.0)[9] libraries. Figures were plotted using the *matplotlib* (version 3.7.2)[10] and *seaborn* (version 0.12.2)[11] libraries.

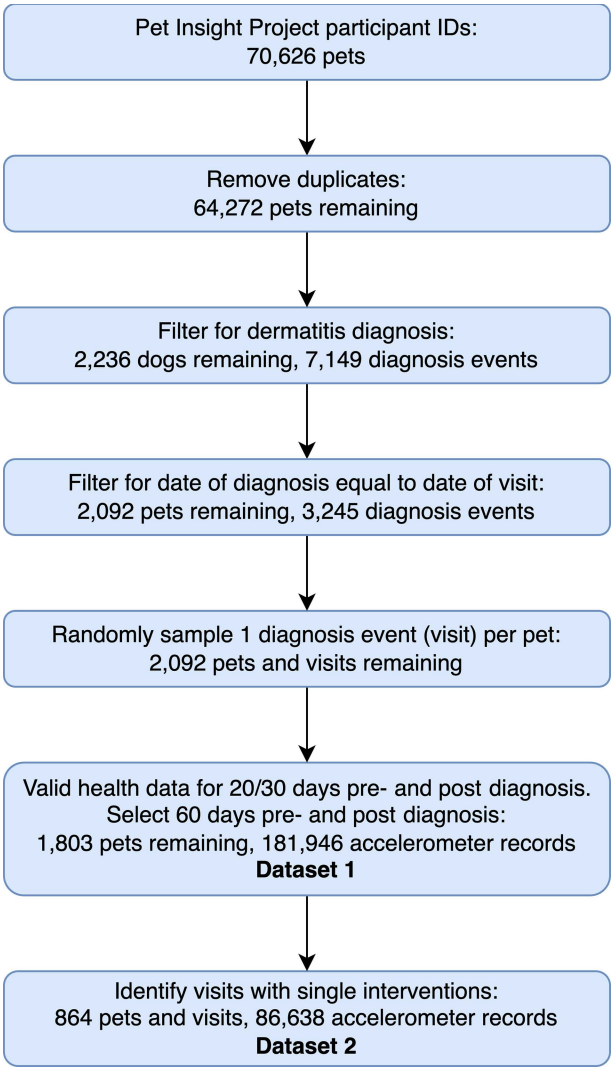

Figure 1—Data selection process for defining dogs, electronic health records, and accelerometer records eligible for this retrospective study of data collected from 1,803 dogs from 2019 through 2023 evaluating the ability of collar-mounted accelerometers to monitor the effects of pruritic canine dermatitis treatment.

Effect of any intervention

The ability of the accelerometer to measure a difference in scratching or licking (pruritic behaviors) after any intervention was estimated using linear regression to model the behaviors in the period after the intervention. The baseline variable was defined as the mean time spent performing the behavior in the 14 days prior to the intervention. The outcome was defined as the mean percentage of change in the pruritic behavior in the 30 days following the visit relative to the baseline. The exposure was the presence or absence of an intervention recorded in the EHR. **Figure 2** displays a directed acyclic graph (DAG)[12] constructed using *DAGitty* (version 3.1, R software package),[13] based on literature and expert opinion, to illustrate the hypothesized scenario and to identify any potential confounders **(Supplementary Table S2)**. The number of previous visits relating to dermatitis was identified as a confounder based on the DAG and was therefore controlled for in the model. The number of previous dermatitis visits may indicate the severity or chronicity of the ailment the dog was experiencing and thus may influence the choice of intervention the pet owner and veterinarian select. The coefficients of the variables in the model are reported along with SEs, *P* values, and 95% CIs.

Differentiating interventions

The accelerometer was assessed for its ability to differentiate outcomes between intervention categories using a linear regression model. The outcome was defined as the mean percentage of change in the pruritic behavior in the 30 days following the visit relative to the baseline (see the definition in the previous section). Intervention category was the exposure, with "no intervention" as the reference category; an additional variable representing the number of previous dermatitis visits was included in the model to control for this potential source of bias. No significant interaction was observed between the number of previous dermatitis visits and intervention type, so an interaction term was not included in the model.

Results

Study population

Dataset 1 consisted of 1,803 dogs, each with 1 randomly sampled dermatitis visit, and dataset 2 consisted of 864 dogs with 1 randomly sampled dermatitis visit and only 1 type of intervention recorded at this visit. The characteristics of these cohorts are summarized in **Table 1**. The measured scratching and licking from the 60 days before and after a dermatitis visit are shown in **Figure 3**. Less than 20% of records require data imputation for both licking and scratching. The mean time per day spent scratching and licking increased prior to the visit and decreased and stabilized below baseline following the visit.

Effect of any intervention

A linear model was fit to dataset 1, with the exposure variable as presence/absence of an intervention in the EHR and the outcome variable as the percentage of change in pruritic behavior, adjusting for number of previous dermatitis visits. The coefficient of intervention on scratching, or treatment effect, was −25.6 ± 4.43 (CI, −34.3 to −16.9; $P < .005$). The coefficient for number of previous dermatitis visits was 0.1 ± 0.60 (CI, −1.09 to 1.27; $P = .88$). The marginal mean percentage of change in scratching following a visit with no intervention (holding number of previous dermatitis visits at its mean value) was 9.0% and −16.6% with an intervention. For licking, the coefficient of intervention was −8.6 ± 5.62 (CI, −19.60 to 2.46; $P = .13$), and number of previous dermatitis visits was 0.04 ± 0.77 (CI, −1.47 to 1.53; $P = .96$). The marginal mean percentage of change in licking following a visit with no intervention was 0.7% and −7.9% for an intervention.

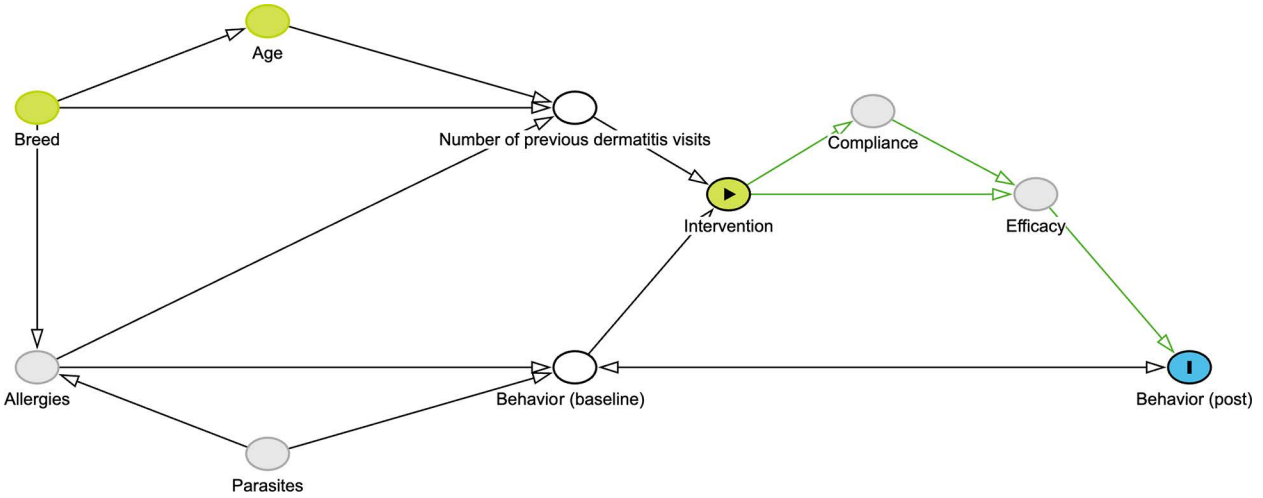

Figure 2—Directed acyclic graph illustrating the hypothesized effect of an intervention on time spent scratching in the period following, used to understand the data-generating process and assumptions in this retrospective study. The green node containing a triangle indicates the exposure variable, empty green nodes represent ancestors of the exposure, the blue node containing a line corresponds to the outcome variable, white nodes represent adjusted variables, and grey nodes represent other variables.

Table 1—Characteristics of the cohort of 1,803 dogs in this retrospective study of data collected from 2019 through 2023 evaluating the ability of collar-mounted accelerometers to monitor effects of pruritic canine dermatitis treatment.

Variable[a]	Dataset 1	Dataset 2
Sex		
Male	985 (55%)	482 (56%)
Female	818 (45%)	382 (44%)
Neuter status		
Neutered	1,725 (96%)	825 (95%)
Intact	78 (4%)	39 (5%)
Intervention category[b]		
Anti-inflammatory	70	14
Antibody	604	235
Antihistamine	278	49
Antimicrobial	732	187
Antiparasitic	354	65
Immunosuppressant	340	87
Pain medication	132	23
Shampoo	242	40
No intervention	164	164
Age (y)	6.2 (3.2)	6.3 (3.2)
Previous dermatitis visits	1.0 (2.1)	0.9 (2.0)
Behavior previsit (s)		
Licking	1,038.9 (918.1)	1,003.7 (895.1)
Scratching	105.2 (123.2)	105.9 (124.9)
Behavior postvisit (s)		
Licking	899.6 (832.9)	892.3 (826.5)
Scratching	82.4 (101.9)	82.9 (100.9)

[a]Categorical variables are represented as counts and percentages; continuous variables are represented as means and SDs. [b]Dogs may be counted in multiple intervention categories.

Differentiating interventions

The change in average daily scratching and licking behaviors in the 30 days after the visit relative to baseline (mean, 14 days before visit) was evaluated for the different selected intervention categories, where dogs have been categorized by chronicity (no previous dermatitis-related visits, low; 1 to 3 previous dermatitis-related visits, medium; and 4 or more previous dermatitis-related visits, high). The raw data suggest that dogs treated with antibody injections showed a decrease in scratching for both low-chronicity dogs (N = 105), medium-chronicity dogs (N = 102), and high-chronicity dogs (N = 28). Immunosuppressant treatment showed a decrease in scratching for low-chronicity dogs (N = 59) but less of an effect for medium-chronicity dogs (N = 22) or high-chronicity dogs (N = 6), potentially due to fewer examples. Antiparasitic treatment also showed some decrease in scratching for low-chronicity dogs (N = 46), medium-chronicity dogs (N = 15), and high-chronicity (N = 4) dogs. Antimicrobial treatment showed a decrease in scratching for low-chronicity dogs (N = 134) and medium-chronicity dogs (N = 42) but a small increase for high-chronicity dogs (N = 11). Dogs receiving no intervention appeared to have a small decrease in scratching for low chronicity (N = 114), medium chronicity (N = 42), and high chronicity (N = 8). Shampoo, pain medication, and anti-inflammatory interventions do not show a particular trend.

A linear model was fit to dataset 2 with the exposure variable as the presence/absence of a specific intervention identified in the EHR. The outcome variable was the percentage of change in pruritic behavior adjusting for number of previous dermatitis visits. The coefficients of each intervention can be interpreted as the average treatment effect as compared to no intervention **(Table 2)**. The mean predicted change in licking and scratching resulting from the models is shown in **Figure 4**. The antibody and immunosuppressant treatments had the largest effect on scratching: a dog with 2 previous dermatitis-related visits would, on average, see a 35.6%

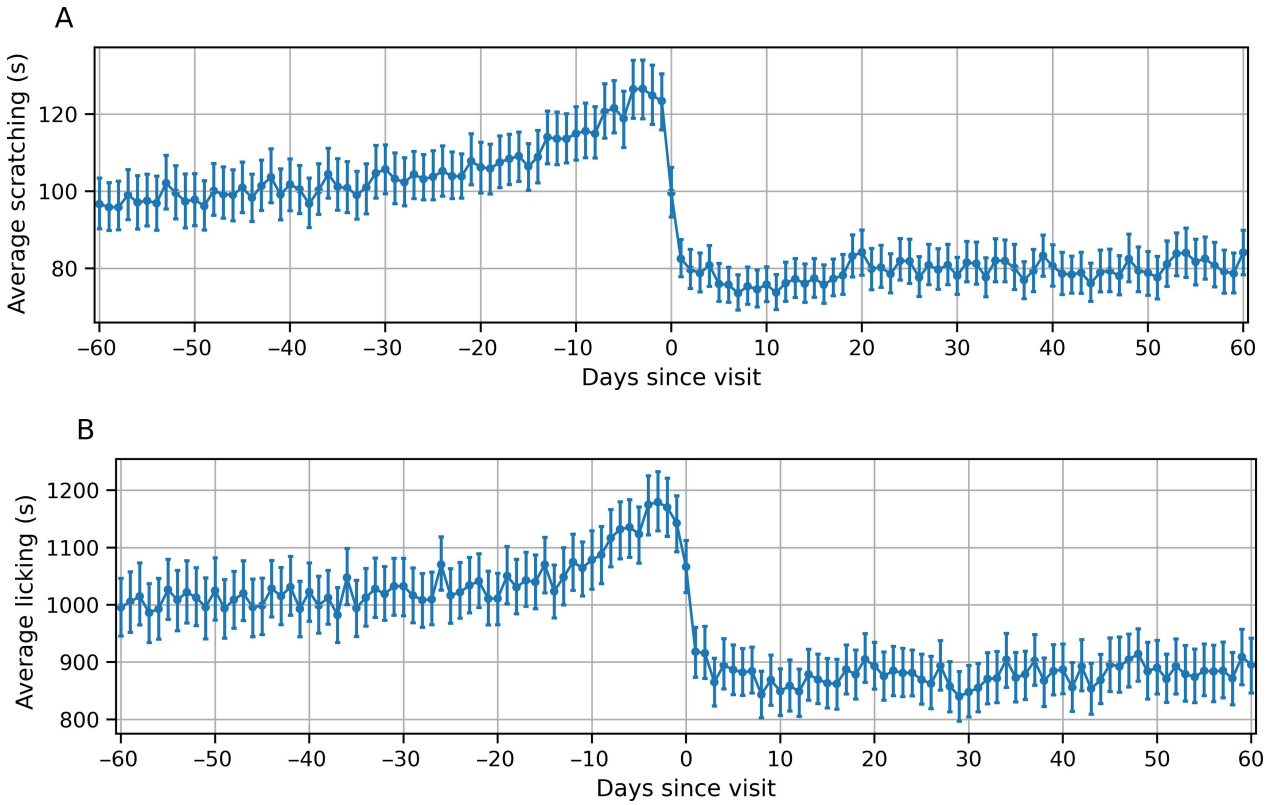

Figure 3—Number of seconds spent scratching (A) or licking (B) recorded in the 60 days leading up to a dermatitis visit and the 60 days following for visits where an intervention was recorded in the electronic health records for the 1,803 dogs within this retrospective study. The error bars represent 95% CIs.

Table 2—Results of the linear mixed-effects model for the effect of each intervention category on scratching and licking for the 864 pets in dataset 2 as described in Table 1.

	Scratching			Licking		
Variable	**Coefficient (95% CI)**	**Error**	***P* value**	**Coefficient (95% CI)**	**Error**	***P* value**
Intercept	7.22 (−1.37 to 15.80)	4.38	.10	0.71 (−7.40 to 8.82)	4.13	.86
Previous dermatitis visits	2.92 (1.00 to 4.85)	0.98	< .005	0.02 (−1.84 to 1.82)	0.93	.98
Intervention						
Anti-inflammatory	−24.95 (−55.25 to 5.36)	15.44	.11	−10.1 (−38.74 to 18.53)	14.59	.49
Antibody	−48.12 (−59.32 to −36.93)	5.70	< .005	−17.98 (−28.55 to −7.40)	5.39	< .005
Antihistamine	−10.50 (−28.23 to 7.22)	9.03	.24	−4.36 (−21.1 to 12.39)	8.53	.61
Antimicrobial	−6.68 (−18.32 to 4.97)	5.93	.26	0.24 (−10.76 to 11.25)	5.60	.96
Antiparasitic	5.66 (−10.30 to 21.62)	8.13	.49	15.77 (0.96 to 30.85)	7.68	.04
Immunosuppressant	−30.62 (−45.06 to −16.19)	7.36	< .005	−20.36 (−34.00 to −6.72)	6.95	< .005
No intervention	Reference category					
Pain medication	−10.73 (−34.97 to 13.51)	12.35	.38	14.74 (−8.17 to 37.63)	11.67	.21
Shampoo	−22.94 (−42.13 to −3.74)	9.78	.02	−3.98 (−22.11 to 14.16)	9.24	.67

The outcome variable is the percentage of change in scratching in the 30 days following the visit relative to the baseline scratching (14-day average previsit). The random effect is pet ID, and the models are adjusted for the number of previous visits related to dermatitis. The error is the SE on the coefficient.

(95% CI, −42.22 to −27.89) decrease in scratching from baseline with antibody treatment and a 17.6% (CI, −29.48 to −5.64) decrease with immunosuppressant treatment. The effects from anti-inflammatory and antimicrobial treatments were less marked, with larger associated *P* values. The effect of intervention on time spent scratching varies by number of previous dermatitis-related visits, where dogs with more previous visits show less response to treatment than those with fewer previous visits. For instance, dogs treated with medicated shampoo on their first visit, on average, have a decrease in scratching of 15.7% (CI, −33.00 to 1.56), which decreases to −1.1% (CI, −20.09 to 17.89) by their sixth visit. The same relationship is not seen for the measurements of time spent licking.

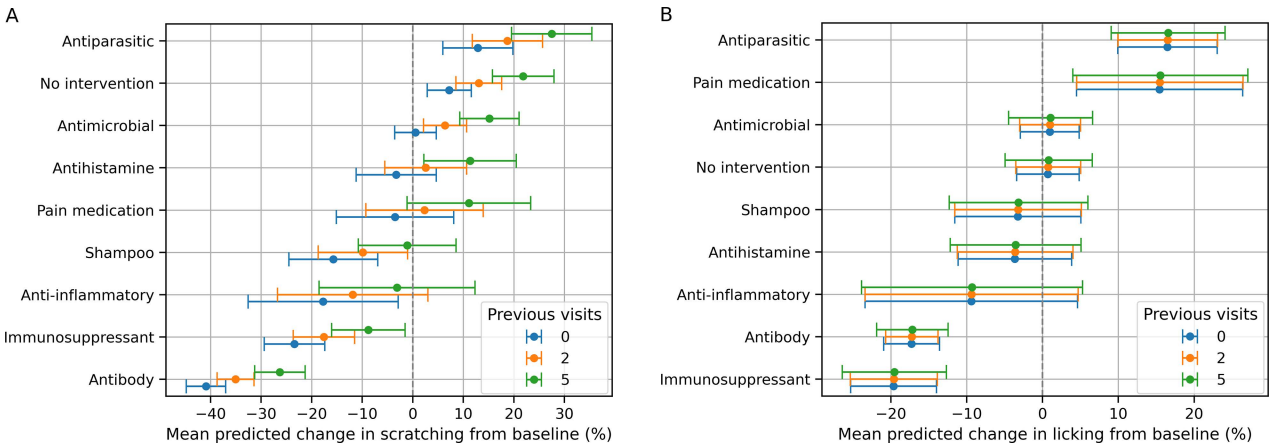

Figure 4—The mean predicted change in scratching (A) and licking (B) from baseline for each intervention category for 0, 2, and 5 previous dermatitis-related visits for the 864 dogs in this retrospective study receiving monotherapy at their visit as described as dataset 2 in Figure 1. Error bars represent the SE of the mean.

Discussion

This study was a retrospective analysis using a large, novel dataset of domestic dogs in real-world environments, providing unique insights into the application of collar-mounted accelerometers for monitoring pruritic behaviors following veterinary-prescribed interventions. The detection of pruritic behaviors makes use of a deep learning algorithm, which has been trained and validated on thousands of pets and samples. These rich, objective measurements are supported by structured EHR data enabled by standardized software used across over 1,000 primary care veterinary practices, allowing access to detailed data on millions of pets. The accelerometer was able to identify changes in pruritic behaviors related to interventions for a range of treatments.

For veterinarians, the ability to monitor a patient's response to treatment remotely and objectively with accelerometers could revolutionize their approach to the management of pruritic skin diseases. This technology provides data-driven insights, allowing for a more nuanced understanding of the patient's condition. By reducing the often-subjective nature of evaluating these behaviors, which can vary greatly among patients and over time, veterinarians can develop more proactive, personalized, and targeted treatment approaches. This could lead to faster relief for the patient and a significant reduction in the chronic, frustrating cycle of dermatitis flareups. Moreover, the study emphasizes the potential of these devices in research settings. This could lead to the development of new treatments and care strategies, further enhancing the quality of life for dogs with this condition.

The effect of an intervention depends on a range of factors, including compliance and efficacy, which depend on the specific condition of the pet and the type of intervention. Compliance was not recorded, and for interventions administered by the pet owner, it is possible that the treatments were not applied correctly or completely. While compliance is a challenge for treatment success, the impact of which was not possible to analyze, the data and alerts provided by the device could potentially positively influence treatment compliance. Diagnosing the underlying cause of a dog's pruritus and determining effective treatment can be challenging, often involving trial and error. For example, interventions may be ineffective if they do not address the specific type of dermatitis affecting the pet or additional complicating features. These omissions or mismatches, along with individual variability and severity in each case, can dilute the observed effects of treatments in studies, introducing variability that complicates the analysis of treatment efficacy. However, identifying an ineffective intervention still provides valuable information, helping veterinarians and pet owners refine their approach to find the most effective treatment for a specific case.

A decreasing effect of intervention with an increasing number of previous visits was observed in measurements of time spent scratching. This may be due to the treatment administered being inappropriate for the condition or confounding factors, such as secondary infections, which often complicate chronic pruritus cases and may have gone unaddressed by the intervention used. While the pet owners may have had additional medications at home or declined more comprehensive treatment plans, these cases highlight that chronic pruritus often requires a multifaceted approach to manage complicating factors effectively. No relationship was observed between efficacy of intervention and number of previous visits on measurements of time spent licking. This could be due to associations between the type of dermatitis condition and pruritus location, which have been observed previously.[1,14] Additionally, pruritus is the primary cause of scratching, but the same is not true for licking as dogs lick for other reasons, such as self-grooming. Only duration of pruritic behavior was measured by the accelerometer; intensity of scratching may provide additional insights into efficacy in that a positive intervention may lead to less vigorous scratching.

This study compared the recorded pruritic behaviors of dogs with interventions recorded in their EHRs to those with no record of an intervention.

It is possible that dogs may have received an intervention that was not recorded in the veterinary notes. Although efforts were made to mitigate this risk by searching through the free text medical notes for mentions of interventions and excluding any pets with mentions of interventions within the timeframe of interest, there may still be dogs incorrectly labeled in this dataset. However, this would reduce the difference between the "intervention" and "no intervention" datasets, weakening the signal of the intervention. It may be expected that the effect determined in this study is potentially weaker than the true effect due to the potential lack of veracity of the "no intervention" subset. Dogs were also categorized by number of previous dermatitis-related visits; however, it is not possible to account for dogs visiting alternative veterinary hospitals.

The time course of treatment effects also varies; while antibody and immunosuppressant treatment show immediate effects, other treatments, like shampoos and antimicrobials, might take longer to manifest results. Various external factors, such as parasites and environmental conditions, can induce pruritic symptoms, and it is impractical to account for all of these variables in a real-world study. Furthermore, the study design often requires isolating the effects of single interventions for clarity, though in clinical practice, multiple treatments are frequently used simultaneously to manage dermatitis. This discrepancy between study conditions and real-world practice can affect the direct assessment of individual treatment impacts. However, the characteristics of these datasets are similar, implying that no bias was introduced by this selection. The requirement of a single intervention additionally impacts the number of eligible records for each treatment as some treatments are less likely to be prescribed in isolation. The number of pets receiving only pain medication or anti-inflammatories was low, limiting the significance of those results.

A DAG was used in this study to determine factors involved in the change in pruritic behaviors under intervention. Directed acyclic diagram are useful tools to elucidate the understanding of the process of interest, allowing input from experts and literature and enabling an understanding of potential bias and confounders. The DAG indicated that the number of previous dermatitis-related visits may affect the causal path of intervention to change in pruritic behavior. This relationship is based on the hypothesis that the response to and choice of intervention may be related to the severity or chronicity of the condition, which can be inferred from the number of previous dermatitis visits. The DAG was informed by literature and expert opinion but may not be a complete representation of the underlying mechanism, which may be more likely considering the relative uncertainty in the understanding of causes of canine pruritus.

This study shows that a collar-mounted accelerometer can be used to detect, measure, and monitor changes in pruritic behaviors. The capacity of these accelerometers to provide quantifiable data on pruritic behaviors introduces a new dimension to pruritus management. Future studies attempting to understand the onset and progression of dermatological conditions could utilize these tools. Additional data could be collected to support the understanding of the care pathways for pets with chronic pruritus. Data on the compliance of interventions and nonveterinary intervention would be valuable information to include in future studies as well as gathering more information on the type, severity, and chronicity of pruritus. The ability to measure intensity alongside duration of scratching may also be a valuable enhancement in future iterations of this technology.

This analysis was a retrospective study of observational data (accelerometer data and EHRs) to determine whether a collar-mounted accelerometer can measure the impact of an intervention and detect differences in impacts between interventions. The data generated by the Pet Insight Project is a novel dataset providing unique opportunities for retrospective studies on pet health and behavior. This study determined that a collar-mounted accelerometer can identify the effect of an intervention on a dermatological issue. Besides providing insights into the impact of an intervention, a supporting application could create a user experience for owners, with compliance tools and timely supporting treatment advice. This supports the use case of accelerometers as health monitoring tools for pets with pruritic skin diseases, leading to improved outcomes by enhancing understanding and informing care pathways.

Acknowledgments

The authors are grateful to the more than 1,000 Banfield clinicians who diligently and consistently recorded their observations in a medical record over the 4-plus-year study period. Without that collective effort, this work would not have been possible.

Disclosures

Dr. O'Rourke, Leah Redford, and Ciaran O'Flynn are employees of Waltham Petcare Science Institute, Mars Science and Diagnostics. Dr. Carson, Scott Lyle, and Dr. Kresnye are employees of At-Home Diagnostics, Mars Science and Diagnostics.

No AI-assisted technologies were used in the generation of this manuscript.

Funding

The authors have nothing to disclose.

ORCID

A. O'Rourke https://orcid.org/0000-0002-7700-3782

References

1. Hensel P, Santoro D, Favrot C, Hill P, Griffin C. Canine atopic dermatitis: detailed guidelines for diagnosis and allergen identification. *BMC Vet Res.* 2015;11(1):196. doi:10.1186/s12917-015-0515-5

2. Den Uijl I, Gómez Álvarez CB, Bartram D, Dror Y, Holland R, Cook A. External validation of a collar-mounted triaxial accelerometer for second-by-second monitoring of eight behavioural states in dogs. *PLoS One.* 2017;12(11):e0188481. doi:10.1371/journal.pone.0188481
3. Griffies JD, Zutty J, Sarzen M, Soorholtz S. Wearable sensor shown to specifically quantify pruritic behaviors in dogs. *BMC Vet Res.* 2018;14(1):124. doi:10.1186/s12917-018-1428-x
4. Wernimont SM, Thompson RJ, Mickelsen SL, Smith SC, Alvarenga IC, Gross KL. Use of accelerometer activity monitors to detect changes in pruritic behaviors: interim clinical data on 6 dogs. *Sensors (Switzerland).* 2018;18(1):249. doi:10.3390/s18010249
5. Chambers RD, Yoder NC, Carson AB, et al. Deep learning classification of canine behavior using a single collar-mounted accelerometer: real-world validation. *Animals (Basel).* 2021;11(6):1549. doi:10.3390/ani11061549
6. Carson A, Wright A, Holland R, Cernicchiaro N, Kresnye C, Lyle S. Comparison of scratching severity between owner: completed pruritus visual analog scale and whistle canine collar. *Vet Dermatol.* 2021;32(5):419–433.
7. Pet Insight Project. Whistle. Accessed May 17, 2023. https://www.whistle.com/pages/pet-insight-project
8. Pandas. Version 1.3.5. December 2021. Accessed January 29, 2024. https://github.com/pandas-dev/pandas
9. Seabold S, Perktold J. *Statsmodels: econometric and statistical modeling with Python*. *Proceedings of the 9th Python in Science Conference*. 2010. doi:10.25080/Majora-92bf1922-011
10. Hunter JD. Matplotlib: a 2D graphics environment. *Comput Sci Eng.* 2007;9(3):90–95. doi:10.1109/MCSE.2007.55
11. Waskom M. Seaborn: statistical data visualization. *J Open Source Softw.* 2021;6(60):3021. doi:10.21105/joss.03021
12. Pearl J. Causal diagrams for empirical research. *Biometrika.* 1995;82(4):669–688. doi:10.2307/2337329
13. Textor J, Hardt J. DAGitty: a graphical tool for analyzing causal diagrams. *Epidemiology.* 2011;22(5):745. doi:10.1097/EDE.0b013e318225c2be
14. Harvey ND, Shaw SC, Blott SC, Vàzquez-Diosdado JA, England GCW. Development and validation of a new standardised data collection tool to aid in the diagnosis of canine skin allergies. *Sci Rep.* 2019;9(1):3039. doi:10.1038/s41598-019-39630-3

Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org.