Journal of Veterinary Internal Medicine

Journal of Veterinary Internal Medicine Open Access
ACVIM American College of Veterinary Internal Medicine

STANDARD ARTICLE OPEN ACCESS
Small Animal Internal Medicine Neurology

Development of a Novel Epilepsy and Dyskinesia Survey for Large-Scale Characterization of Seizure Semiology in Dogs

Madlen S. Matz[1] | Tiina Harmas[2,3,4] | Franziska Wielaender[1] | Emma Hakanen[2,3,4] | Jasmin N. Nessler[5] | Holger A. Volk[5] | Andrea Tipold[5] | Paul J. J. Mandigers[6] | Tarja S. Jokinen[7] | Luisa De Risio[8] | Sally L. Ricketts[9] | Marjo K. Hytönen[2,3,4] | Thomas Parmentier[10,11] | Fiona James[12] | Sofie F. M. Bhatti[13] | Gerhard Kluger[14,15] | Hannes Lohi[2,3,4] | Andrea Fischer[1]

[1]Small Animal Clinic, Centre for Clinical Veterinary Medicine, LMU Munich, Munich, Germany | [2]Department of Clinical and Medical Genetics, University of Helsinki, Helsinki, Finland | [3]Department of Veterinary Biosciences, University of Helsinki, Helsinki, Finland | [4]Folkhälsan Research Center, Helsinki, Finland | [5]Department Small Animal Medicine and Surgery, University of Veterinary Medicine Hannover, Hanover, Germany | [6]Department of Clinical Sciences, Utrecht University, Utrecht, the Netherlands | [7]Department of Equine and Small Animal Medicine, University of Helsinki, Helsinki, Finland | [8]Linnaeus Veterinary Limited, Shirley, West Midlands, UK | [9]Canine Genetics Centre, Department of Veterinary Medicine, University of Cambridge, Cambridge, UK | [10]Faculte de Medicine Veterinaire, Universite de Montreal, Montreal, Canada | [11]Centre Interdisciplinaire de Recherche sur le Cerveau et lÀpprentissage, Universite de Montreal, Montreal, Canada | [12]Department of Clinical Studies, University of Guelph, Guelph, Canada | [13]Faculty of Veterinary Medicine, Ghent University, Merelbeke, Belgium | [14]Research Institute "Rehabilitation, Transition, Palliation", Paracelsus Medical University Salzburg, Salzburg, Austria | [15]Clinic for Neuropediatrics and Neurorehabilitation, Epilepsy Center for Children and Adolescents, Schön Klinik Vogtareuth, Vogtareuth, Germany

Correspondence: Hannes Lohi (hannes.lohi@helsinki.fi)

Received: 12 November 2024 | **Revised:** 10 March 2025 | **Accepted:** 11 March 2025

Funding: This work was supported by the Finnish Society of Science and Letters, the Epilepsy Foundation, the Agria Foundation (N2022-0018), the Jane and Aatos Erkon Säätiö, American Kennel Club Canine Health Foundation (03039, 2566), and the University of Helsinki DVM Doctoral Program.

Keywords: epidemiology | movement disorder | paroxysmal event | phenotype | seizure classification | veterinary neurology

ABSTRACT

Background: Diagnosing epilepsy and dyskinesia in dogs relies on seizure semiology, laboratory workup, brain imaging, and electroencephalography. Variability in existing epilepsy surveys complicates comparison and impedes epidemiologic and genetic research.

Objective: To characterize the semiology of epileptic seizures and dyskinesia episodes using a novel, owner-completed, multi-language online questionnaire.

Animals: A cohort of 606 dogs from 96 breeds with paroxysmal events, perceived by their owners as epilepsy or dyskinesia.

Materials and Methods: A comprehensive epilepsy and dyskinesia questionnaire featuring pragmatic seizure categories and video upload was developed in German, Finnish, and English. The reliability of the questionnaire was assessed, and the study cohort analyzed.

Results: The questionnaire demonstrated strong internal consistency and interrater agreement. Owners correctly classified paroxysmal events in 90.1% of cases (95% CI 88.18–92.11). Video footage was submitted from 23.8% (143/606) and supported the seizure type in the questionnaire in 96.5%. The age of onset ranged from 6 months to 6 years in 80.2% (median 2 years; IQR 1–5 years). Generalized (epileptic) convulsive seizures occurred in 58.6% of dogs, non-generalized paroxysmal motor events

Abbreviations: ASM, anti-seizure medication; CT, computed tomography; EEG, electroencephalography; ILAE, International League Against Epilepsy; IVETF, International Veterinary Epilepsy Task Force; MRI, magnetic resonance imaging.

Hannes Lohi and Andrea Fischer contributed equally as 17th authors.

without convulsions in 58.1%, sudden falls without movement in 6.1%, episodes of impaired awareness in 15.8%, and other unclassified events in 7.1%. Multiple seizure types were reported in 25.2% of the dogs. Labrador Retrievers exhibited a higher prevalence of non-generalized motor events compared to Border Collies, Siberian Huskies, and other breeds ($p < 0.001$).
Conclusions: The questionnaire reliably characterizes epileptic seizures and dyskinesia episodes in dogs, making it a valuable tool for large-scale epidemiological and genetic studies.

1 | Introduction

Epilepsy and dyskinesia are neurological disorders in dogs with overlapping clinical features, posing diagnostic and therapeutic challenges for veterinarians [1–4]. Epilepsy is the most common chronic central nervous system disorder in dogs, affecting 0.43%–0.82% of those seen in veterinary practices [2, 5–7]. The classifications of seizure types and epilepsies in dogs were established by the International Veterinary Epilepsy Task Force (IVETF) in 2015 [1], and for humans in 2017 by the International League Against Epilepsy (ILAE) [8, 9] and recently updated in 2024 (www.ilae.org). Non-epileptic movement disorders including paroxysmal dyskinesia in dogs are described by the International Veterinary Dyskinesia Task Force in 2021 [4, 10].

In humans, seizure classification is primarily based on the seizure semiology due to the limited availability of video-electroencephalography (EEG) and supported by additional findings from EEG, magnetic resonance imaging (MRI), blood results, or genetic testing when available [9]. Classification is essential to identify epilepsy syndromes and movement disorders associated with specific ages of onset, comorbidities, and prognosis and therapeutic concepts [8, 9, 11, 12]. Numerous genes linked to epilepsy syndromes or neurodevelopmental disorders and specific phenotypes have been identified [13, 14]. Recently, the classification of epilepsies based on seizure semiology and age of onset was further updated in humans [15–17].

In veterinary medicine, breed-specific epilepsies, along with subtle variations in seizure types and responses to anti-seizure medications (ASMs), point to a strong genetic background [2, 18–28], a trend also seen in paroxysmal dyskinesias [29, 30]. Currently, most epidemiological and genetic investigations of these conditions rely on owner-completed questionnaire data [23, 26, 28]. Interestingly, in human medicine, genes associated with epilepsy frequently overlap with those linked to movement disorders [31]. In genetic epilepsies and autoimmune encephalitis in humans, movement disorders such as dystonia, ataxia, or choreoathetosis frequently co-occur with seizures [31]. Additionally, ASMs may also be effective as anti-dystonic agents [4, 12].

Large multicentric clinical study cohorts are essential to uncover the complex genetic backgrounds of epilepsy, and harmonized datasets are of paramount importance to obtain the necessary statistical power for genetic discovery studies [32–34]. Additionally, harmonized datasets enable the identification of genetic variants that may be prevalent in specific breeds or populations, paving the way for more targeted treatment strategies [2, 13, 14]. These large-scale studies depend on international collaborations and data sharing among researchers [13, 33, 34].

Veterinary medicine currently lacks standardized questionnaires capable of capturing the variability of seizures and dyskinesia episodes across breeds. Existing questionnaires often collect less detailed information on whether a dog exhibits more than one type of seizure or episodic event, as recommended by the IVETF [23, 26, 35, 36]. To address these gaps, this study aimed to develop a comprehensive questionnaire designed to accurately characterize the semiology of various seizures and dyskinesia episodes, enabling more precise phenotyping in large cohorts of dogs.

2 | Materials and Methods

2.1 | Epilepsy and Dyskinesia Questionnaire

A novel multi-language epilepsy and dyskinesia questionnaire was developed (Figure 1). The questionnaire provided video examples of various motor and non-motor paroxysmal events, as well as options for users to upload their own video footage and diagnostic test results. The questionnaire (Figure 1) was designed to allow for comprehensive and consistent descriptions of the semiology of epileptic seizures and paroxysmal events in dogs with epileptic seizures, dyskinesia, or both [1, 20, 21]. A dog's seizures or paroxysmal events were categorized into five types and labeled A–E: Type A, generalized (epileptic) convulsive seizures; Type B, non-generalized motor events; Type C, sudden falls without movement; Type D, episodes associated with impaired awareness; and Type E, other unclassified episodes with abnormal movements or behavior. The questionnaire was made available as an interactive online tool (www.dogepilepsyresearch.org) in English, Finnish, and German. It featured five sections: seizure descriptions, possible reasons, veterinary examinations, medication and diet, and interictal behavior (Figure 1). For the seizure description section, dog owners were asked to describe the seizures or episodes in three different modes. Thereby they had to follow a three-step procedure in a predetermined order: (1) initially with free text with their own words, (2) then they were shown example videos and asked to assign their dog's seizures to a specific seizure type (A, Video 1, https://youtu.be/Ox2Y2dK-A4xU; B, Video 2, https://youtu.be/O3lqzxT2GZ4; C, Video 3, https://youtu.be/aJgbUvM4MKk; D, Video 4, https://youtu.be/PYuMFd4U7VU) or E, other unclassified episodes and (3) then by answering detailed questions on the semiology and occurrence of the episodes (age at onset, frequency, prodromal signs, signs at the onset, motor signs, autonomic signs, posture, responsiveness, duration, postictal signs) for each chosen seizure type. A key feature of the questionnaire was the ability for owners to select multiple seizure types and provide detailed answers for each type, starting with the most common event. The platform included an option to upload video footage of seizures and medical records. The total number of

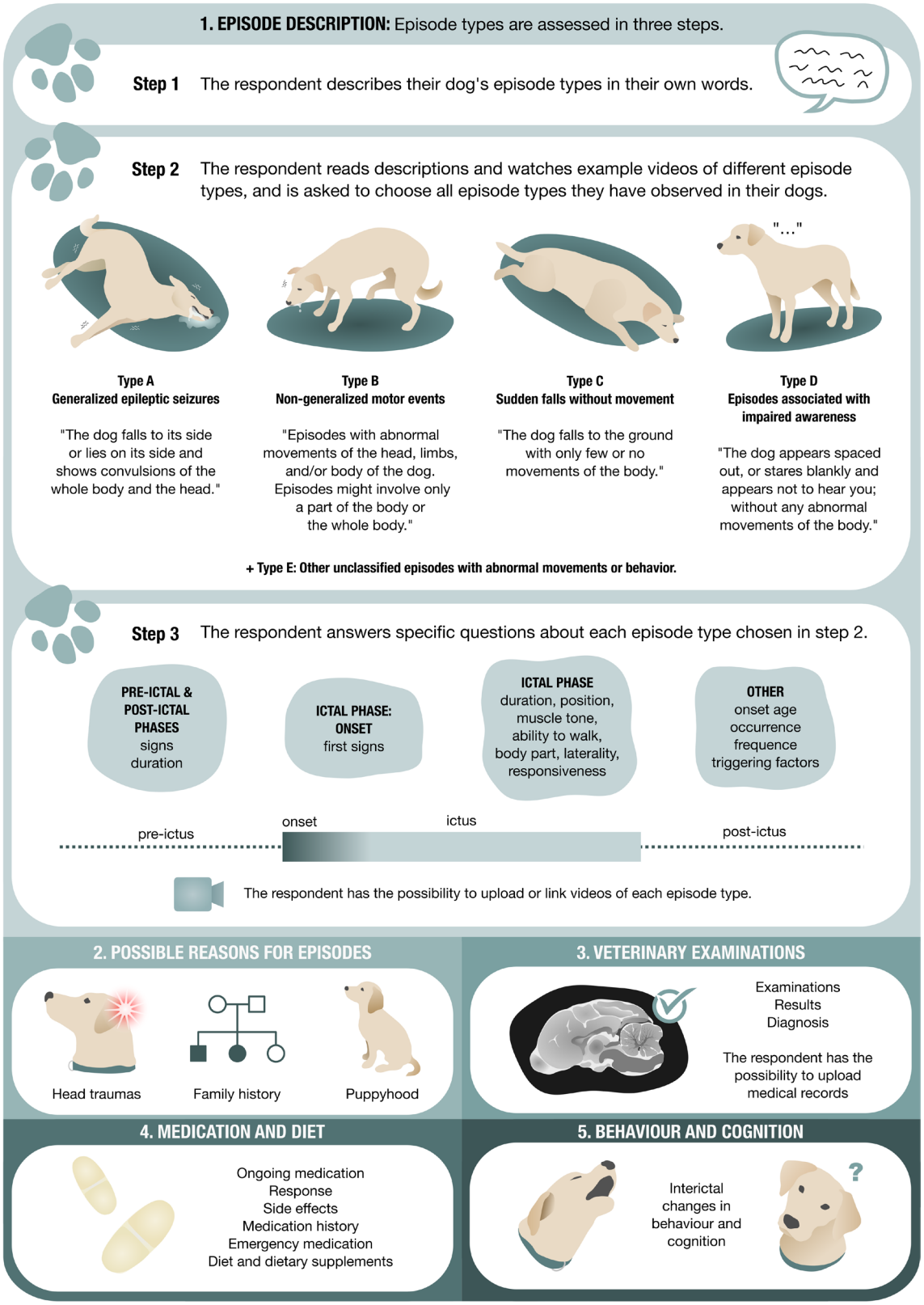

FIGURE 1 | Structure of the epilepsy and dyskinesia questionnaire.

questions ranged from 39 to 455 as the interactive questionnaire comprised single-choice, multiple-choice, and free-text questions (File S1). The design process and initial validation steps are described in File S2.

2.2 | Data Collection

The use of the survey and data collection for this research was approved by the institutional ethics committee (ref:

243-01-12-2020). The questionnaire was distributed to participants from the general dog population in Germany, Finland, and the United Kingdom between October 2021 and May 2023. The epilepsy and dyskinesia questionnaire was promoted via social media, including breed-specific and epilepsy/dyskinesia-focused Facebook groups. Several breeding clubs also helped distribute the questionnaire (Labrador Retriever, Rottweiler, Huskies). Owners could share personal data, but according to the data protection agreement, only anonymized datasets were shared with consortium members.

2.3 | Data Cleaning

Duplicate cases were removed, and datasets were included only if the owner had completed all five sections of the questionnaire. Inclusion criteria required that the respondent indicated the dog had experienced at least two seizures or episodes on separate days, with at least 24 h between events, and provided answers to the section with detailed questions. Episodes that were challenging to classify as either epileptic seizures or dyskinesia were also included in the study. Datasets indicating structural epilepsy remained in the study, which focused on seizure semiology and questionnaire validation.

2.4 | Reliability

Consistency in describing the seizures or episodes was evaluated for each case by comparing the owner's classification, free-text descriptions, and responses to detailed questions. Video footage, when available, was also reviewed. Complete agreement was noted when all descriptions and video footage aligned, while partial agreement was recorded if two descriptions and video footage matched. The dog owner's classification of a seizure or episode as Type A–E was compared with the classification of the authors. All assessments were made by consensus (reviewer group 1, A.F./M.S.M).

For interrater agreement of the seizure descriptions, the classifications (Types A–E) were compared across 60 dogs by two additional reviewer groups (reviewer group 2, A.T./J.N.N.; reviewer group 3, P.J.J.M./T.S.J.), who jointly evaluated the same 60 dogs, including standard and uncommon presentations. The 60 dogs included 12 for each seizure type (A–E). These were divided into straightforward cases with consistent descriptions (complete agreement) and challenging cases with variable descriptions (partial/no agreement). Half of the dogs in each subgroup exhibited one seizure type; the other half showed multiple types. The group included dogs with and without video footage. This comparison aimed to assess the level of agreement between the two additional reviewer groups and reviewer group 1, focusing on their interpretations of free-text descriptions and detailed questions, and how each group classified different seizure types and video footage. Six reviewers independently evaluated 25% of the cases with submitted video footage to further investigate interrater agreement in the interpretation of video footage.

Owners' satisfaction with the questionnaire was evaluated through a feedback survey given to the German participants.

2.5 | Exploring Individual Seizure Signs and Breeds

Differences in seizure signs between Type A (generalized [epileptic] convulsive seizures) and Type B (non-generalized motor events) were examined for all dogs whose owners correctly identified the seizure type. Differences in signs between Type A and Type B were further explored with multivariable analysis.

Additionally, the study examined how many dogs exhibited a focal onset in seizure Type A and how this onset presented; Type B episodes were further screened for seizure semiology suggestive of paroxysmal dyskinesia based on previously published consensus criteria [10]. These criteria included episode duration (which may be prolonged), awareness, absence of autonomic signs and postictal behavioral changes, and the absence of postictal changes. Differences in seizure types between the three most common breeds and the rest of the study cohort were also explored.

2.6 | Statistics

Descriptive statistics were used to summarize the data, and the interquartile range (IQR) was calculated to distribute the age of onset for the study cohort. Kappa statistics were employed to assess interrater agreement. Chi-square test, Fisher's exact test, and odds ratios compare the frequency of individual seizure signs between seizure types. To further compare the differences between Type A and Type B episodes, a multivariable model using logistic regression (glm function) was performed (File S3). Variables were prioritized for inclusion in the multivariable model fitting process based on Fisher's exact test results. Logistic regression was performed using the generalized linear model (GLM) framework, with stepwise model selection implemented via the Akaike information criterion (AIC). The model performance was assessed using area under the curve (AUC) values, which were calculated using the original cohort and validated in a replication cohort (179 Type A, 167 Type B, German, Finnish, and English cases). The AUC values were calculated using the pROC package to evaluate the predictive performance of the model.

All statistical analyses were performed with R version 4.4.1.

3 | Results

3.1 | Study Cohort

Completed questionnaires with responses to all five sections were available from 606 dogs (Table 1). Video footage was provided for 23.6% (143/606) of the dogs.

The 606 dogs represented 96 breeds (Figure 2, File S4) with the most common breeds being Labrador Retrievers, Siberian Huskies, and Border Collies. The median age was 6 years (IQR 4–9 years); 58.3% were male (353/606) and 41.7% (253/606) female dogs. Most dogs (92%; 558/606) were still alive when owners completed the questionnaire study. The median age at the onset was 2 years (IQR

TABLE 1 | Characteristics of the study cohort.

	All dogs	German	Finnish	English
	606	300	175	131
Age of onset				
< 6 months	4.3% (26/606)	2.0% (6/300)	6.3% (11/175)	6.8% (9/131)
6 months to 6 years	80.2% (486/606)	80.7% (242/300)	78.3% (137/175)	81.8% (107/131)
> 6 years	15.5% (94/606)	17.3% (52/300)	15.4% (27/175)	11.4% (15/131)
Sex				
Male	58.3% (353/606)	60.7% (182/300)	57.1% (100/175)	54.2% (71/131)
Intact	40.8% (144/353)	54.9% (100/182)	30.0% (30/100)	19.7% (14/71)
Neutered	59.2% (209/353)	45.1% (82/182)	70.0% (70/100)	80.3% (57/71)
Female	41.7% (253/606)	39.3% (118/300)	42.9% (75/175)	45.8% (60/131)
Intact	40.7% (103/253)	47.5% (56/118)	42.7% (32/75)	25.0% (15/60)
Neutered	50.3% (150/253)	52.5% (62/118)	57.3% (43/75)	75.0% (45/60)
Seizure/episode type				
Type A (generalized (epileptic) convulsive seizures)	58.6% (355/606)	75.0% (225/300)	54.6% (96/175)	25.9% (34/131)
Type B (non-generalized motor events)	58.1% (352/606)	44.7% (134/300)	60.6% (106/175)	85.5% (112/131)
Type C (sudden falls without movement)	6.1% (37/606)	7.3% (22/300)	4.6% (8/175)	9.9% (13/131)
Type D (episodes associated with impaired awareness)	15.8% (96/606)	17.7% (53/300)	17.1% (30/175)	9.9% (13/131)
Type E (other unclassified episodes with abnormal movements or behavior)	7.1% (43/606)	8.6% (26/300)	4.6% (8/175)	6.8% (9/131)
Blood examination	82.3% (499/606)	89.3% (268/300)	74.3% (130/175)	77.1% (101/131)
Normal	85.8% (428/499)	83.2% (223/268)	90.8% (118/130)	86.1% (87/101)
Abnormal	9.0% (45/499)	11.6% (31/268)	5.4% (7/130)	6.9% (7/101)
No information	5.2% (26/499)	5.2% (14/268)	3.8% (5/130)	6.9% (7/101)
Neurologic exam	55.3% (335/606)	60.0% (180/300)	49.7% (87/175)	51.9% (68/131)
Normal	87.8% (294/335)	85.0% (153/180)	93.1% (81/87)	88.2% (60/68)
Abnormal	8.0% (27/335)	11.7% (21/180)	3.4% (3/87)	4.4% (3/68)
No information	4.2% (14/335)	3.3% (6/180)	3.4% (3/87)	7.4% (5/68)
Brain imaging				
MRI	21.2% (129/606)	23.3% (70/300)	25.7% (45/175)	10.7% (14/131)
Normal	83.7% (108/129)	77.1% (54/70)	95.5% (43/45)	78.6% (11/14)
Abnormal	10.1% (13/129)	12.9% (9/70)	4.5% (2/45)	14.3% (2/14)
No information	6.2% (8/129)	10.0% (7/70)	0.0% (0/45)	7.1% (1/14)
CT	6.4% (39/606)	10.0% (30/300)	3.4% (6/175)	2.3% (3/131)
Normal	79.5% (31/39)	73.3% (22/30)	100.0% (6/6)	100.0% (3/3)
Abnormal	7.7% (3/39)	10.0% (3/30)	0.0% (0/6)	0.0% (0/3)
No information	12.8% (5/39)	16.7% (5/30)	0.0% (0/6)	0.0% (0/3)

(Continues)

TABLE 1 | (Continued)

	All dogs	German	Finnish	English
EEG	3.3% (20/606)	3.7% (11/300)	2.9% (5/175)	3.1% (4/131)
Normal	85.0% (17/20)	100.0% (11/11)	60.0% (3/5)	75.0% (3/4)
Abnormal	15.0% (3/20)	0.0% (0/11)	40.0% (2/5)	25.0% (1/4)
No information	0.0% (0/20)	0.0% (0/11)	0.0% (0/5)	0.0% (0/4)
CSF	14.2% (86/606)	22.3% (67/300)	3.4% (6/175)	9.9% (13/131)
Normal	88.4% (76/86)	86.6% (58/67)	100.0% (6/6)	92.3% (12/13)
Abnormal	4.6% (4/86)	4.5% (3/67)	0.0% (0/6)	7.7% (1/13)
No information	7.0% (6/86)	8.9% (6/67)	0.0% (0/6)	0.0% (0/13)
Treatment				
Current medication with ASM	58.1% (352/606)	74.0% (222/300)	46.3% (81/175)	37.4% (49/131)
Previous medication with ASM	10.6% (64/606)	14.7% (44/300)	6.3% (11/175)	6.9% (9/131)
Special diet	42.6% (258/606)	57.3% (172/300)	24.0% (42/175)	33.6% (44/131)
Dog still alive				
Yes	92.1% (558/606)	94.3% (283/300)	84.0% (147/175)	97.7% (128/131)
No	7.9% (48/606)	5.7% (17/300)	16.0% (28/175)	2.30% (3/131)

1–5 years); 80.2% (486/606) experienced their first seizure or episode between 6 months and 6 years of age (Figure 3).

Fifty-five percent (55.3%; 335/606) of all dogs underwent neurological examinations, 82.3% (499/606) had blood tests, and 14.2% (86/606) underwent cerebrospinal fluid analyses. A total of 46.6% (281/606) of dogs underwent diagnostic steps for IVETF Tier 1 (blood tests, neurological examination), 15.5% (94/606) for IVETF Tier 2 (blood tests, neurological examination, brain imaging), and 2.3% (14/606) for IVETF Tier 3 (Tier 2 with EEG) diagnostic level [20]. The IVETF criteria are internationally recognized guidelines for testing for dogs with epilepsy to determine the level of confidence in a diagnosis of idiopathic epilepsy. MRI of the brain was performed in 21.2% (129/606) and computed tomography (CT) in 6.4% (39/606). Owners reported abnormal MRI findings in 10.1% (13/129), normal findings in 83.7% (108/129), and no information in 6.2% (8/129); abnormal CT findings in 7.7% (3/39), normal findings in 79.5% (31/39), and no information in 12.8% (5/39). Based on owner reports, 58.1% (352/606) of dogs were on current medication, 10.6% (64/606) had been on previous medication, and 42.6% (258/606) were on a special diet (Table 1).

3.2 | Classification of Paroxysmal Events

Dog owners classified 58.6% (355/606) of events as Type A (generalized convulsive seizures). Type B episodes (non-generalized motor events without convulsions) were reported in 58.1% (352/606). Type C episodes (sudden falls without movement) were observed in 6.1% (37/606), and Type D episodes (impaired awareness) in 15.8% (96/606). Unclassified episodes with abnormal movements or behavior were labeled as Type E in 7.1% (43/606). Multiple seizure types were reported in 25.2% (153/606) of dogs, totaling 883 distinct events in the study cohort (Figure 4). A review of the seizures and episodes with consistent descriptions and corresponding videos (23.6%; 143/606 dogs) confirmed that Type A seizures involved generalized (epileptic) convulsive seizures (most often tonic–clonic), and Type B episodes (motor, non-convulsive) included various motor events without generalized (epileptic) convulsions, with and without loss of responsiveness. These episodes encompassed a combination of signs suggestive of focal epileptic seizures (e.g., chewing, facial twitches, unresponsiveness, urination, postictal phase) or a combination of signs suggestive of paroxysmal dyskinesia (e.g., dystonia, lifting of one limb, responsiveness, no postictal phase) [22]. Additionally, other isolated motor phenomena were observed, such as episodes of head tremor, tremor of the body or limbs, teeth grinding, head tilt, facial twitches, myoclonic jerks suggestive of myoclonic seizures (e.g., single or repetitive electric shock-like jerks), and undefined motor episodes. Type C involved negative motor signs, such as sudden collapse, resembling atonic seizures or syncope wherein the dogs fell to the ground or onto their side without any apparent motor movements, sometimes accompanied by loss of urine. Type D episodes were characterized by unresponsiveness, where the dogs appeared to stare into space with behavioral arrest (freezing), sometimes accompanied by eyelid twitching or salivation.

3.3 | Reliability

The dog owner's classification of a seizure or episode as Type A–E matched the classification by reviewer group 1 in 90.1% (796/883; 95% CI 88.18–92.11) of the paroxysmal events, and best for Type A 95.5%, followed by Type B 85.6%, Type D 85.4%, and Type C 62.2%. Video footage was available for 143 dogs and supported the seizure type described in the questionnaire in 96.5% (138/143; Table 2). Consistent descriptions of the seizures or episodes were provided for 96.4% (584/606; 77.8% complete,

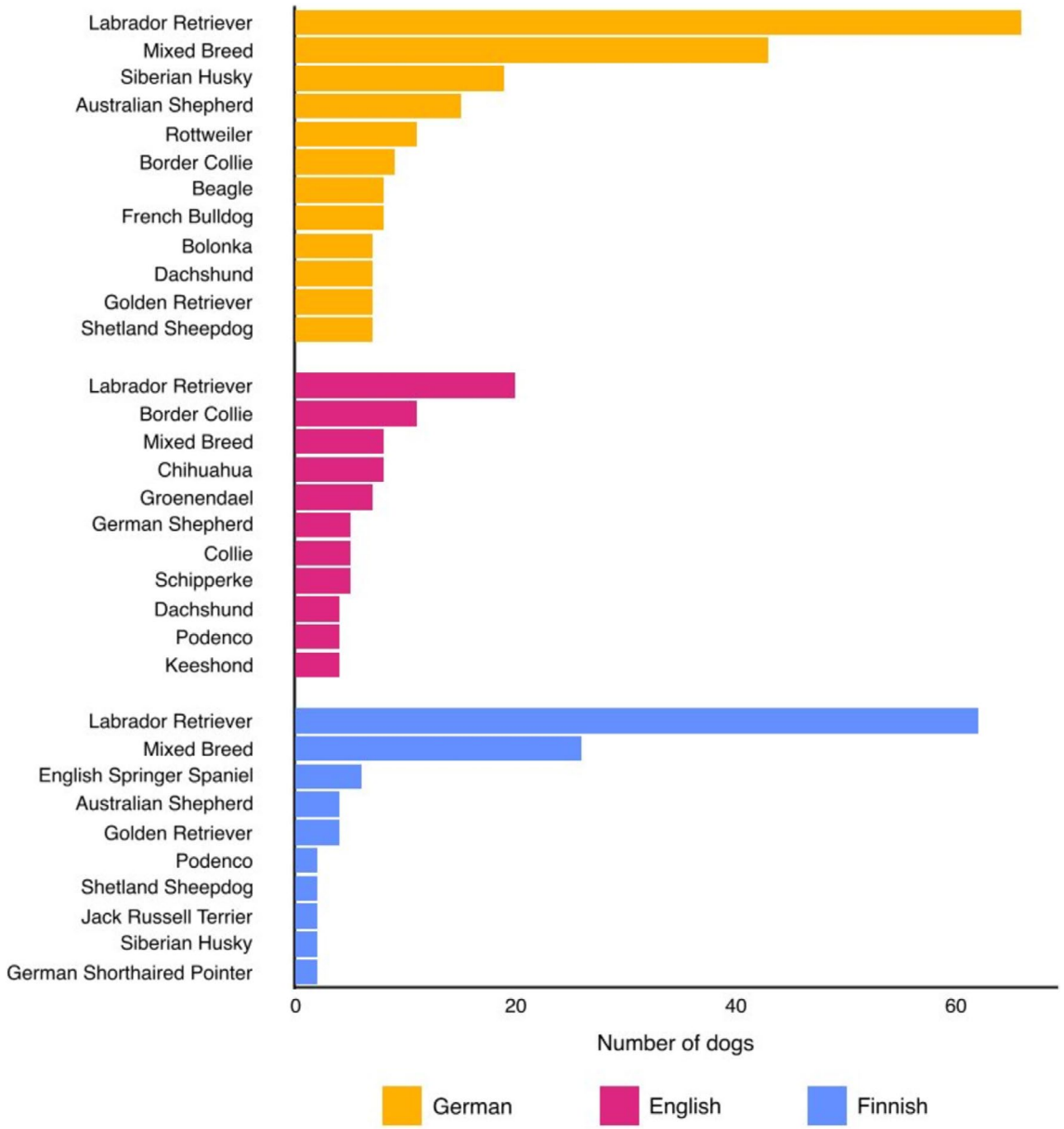

FIGURE 2 | The most common breeds in the study cohort.

18.5% partial agreement), and inconsistent descriptions for 3.6% (22/606) of the study cohort (Table 2). Specifically, Type A descriptions were consistent in 94.7% (338/355), Type B in 87.2% (307/352), Type D in 84.4% (81/96), Type C in 62.2% (23/37), and Type E in 58.1% (25/43) of the paroxysmal events. The review indicated that the free text descriptions were incorrect or too brief in 11.1% (67/606), for example, the owners stated "my dog has seizures," and that the answers to the detailed questions were inadequate in 3.6% (22/606) of the dogs. Videos differed from descriptions in the questionnaire in five dogs (Dog 1: classified A, described A, video B; Dog 2: classified B, described B, video D; Dog 3: classified B, descriptions did not agree, video showed sleep; Dog 4: classified A, B, C, descriptions did not agree, video showed B; Dog 5: classified C, descriptions did not agree, video E).

3.4 | Interrater Agreement

Among 60 dogs with all seizure types, including multiple seizures and inconsistent descriptions, the mean interrater agreement was 86.5%. Video footage was available from 13 of these 60 dogs (18 videos). There was strong agreement between reviewers in interpreting Type A and B seizures or episodes (Cohen's κ 0.73–0.96; File S5). Reviewer groups 1 and 3 showed moderate agreement in interpreting the detailed questions regarding Type D (Cohen's κ 0.50).

The interrater agreement in video interpretation and assignment of Type A–E based on video footage was excellent (Fleiss' κ 0.89; File S5).

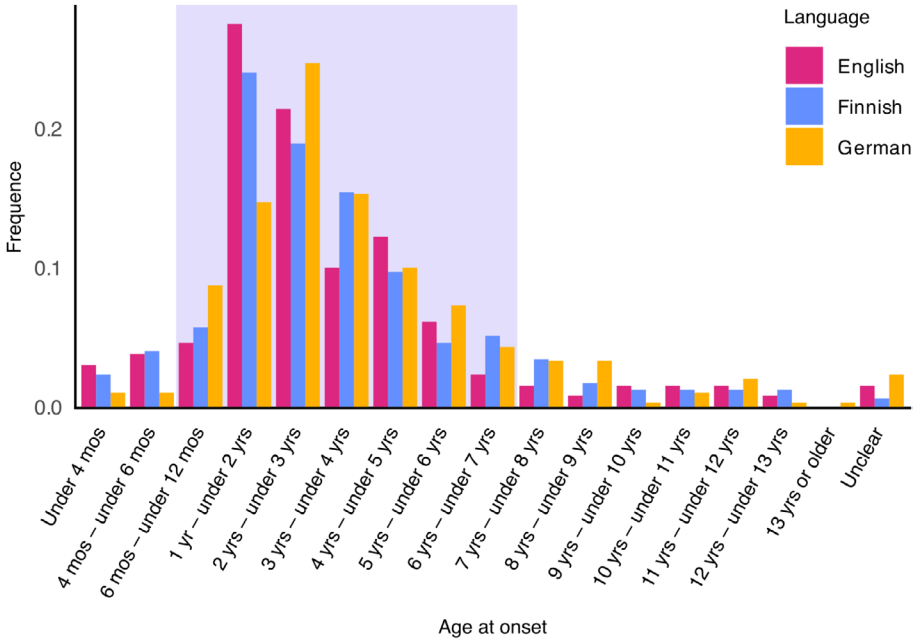

FIGURE 3 | Age of onset in the study cohort.

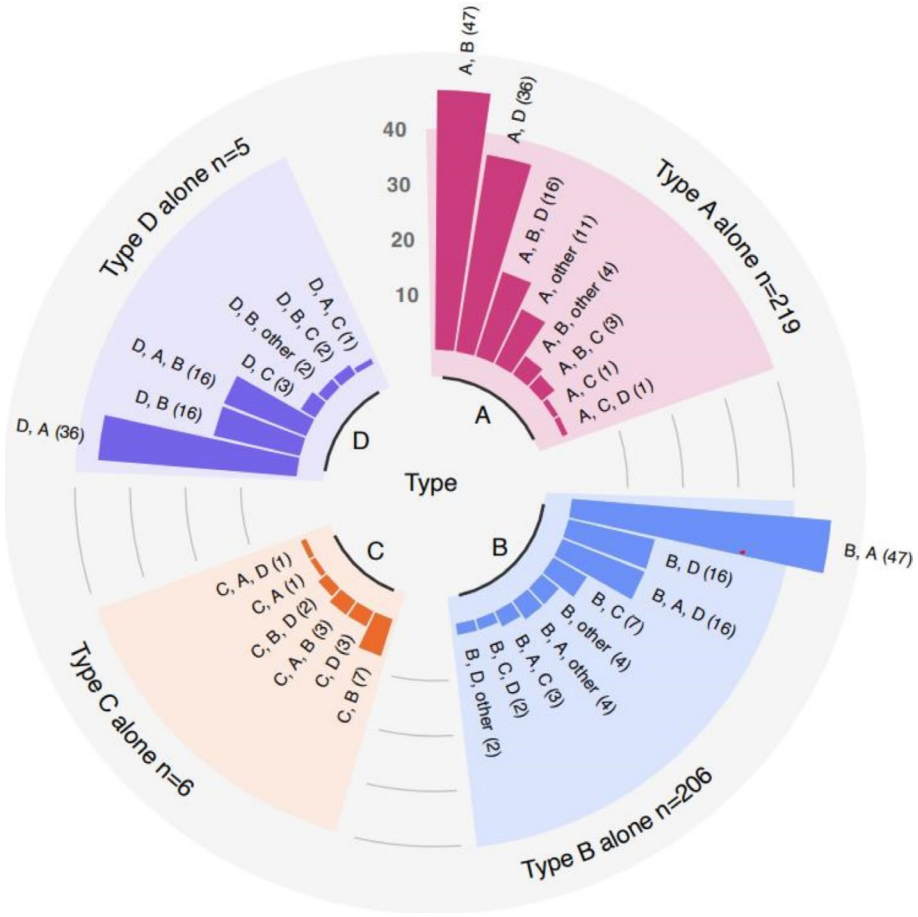

FIGURE 4 | Occurrence of multiple seizure types.

3.5 | Usability of the Questionnaire

The median time to complete the questionnaire was 25 min (IQR 15–40). Seventy-one percent found it easy to complete the questionnaire, 25% were neutral, and 4.0% found it challenging. Eighty-one percent (251/310) were satisfied with the data protection details, while 19.0% (59/310) did not read them (File S6).

TABLE 2 | Reliability of the questionnaire and video footage.

	Video footage		Descriptions in the questionnaire			
	n	Agreed with questionnaire	*n*	Agreed completely	Agreed partially	Agreed not
All questionnaires[a]	143	96.5% (138/143)	606	77.9% (472/606)	18.5% (112/606)	3.6% (22/606)
German	87	97.7% (85/87)	300	80.0% (240/300)	16.0% (48/300)	4.0% (12/300)
English	45	93.3% (42/45)	131	76.3% (100/131)	22.1% 29/131	1.5% 2/131
Finnish	11	100.0% (11/11)	175	75.4% (132/175)	20.0% (35/175)	4.6% (8/175)
Questionnaires without video footage	N/A	N/A	463	76.9% (356/463)	20.1% (93/463)	3% (14/463)
Questionnaires with video footage[b]	143		143	81.8% (116/143)	12.6% (19/143)	5.6% (8/143)

[a]Twenty-nine additional completed questionnaires were submitted from Canada in English and French; descriptions agreed completely in 79.3% (23/29) and partially in 20.3% (6/29).
[b]The assessment of reliability was conducted separately for the groups with and without videos, and the results did not differ significantly ($\chi^2 = 4.9728$, $p = 0.0832$).

3.6 | Exploring Individual Seizure Signs

A comparison of generalized (epileptic) convulsive seizures (Type A, 339 complete records) and non-generalized paroxysmal motor episodes (Type B, 291 complete records) demonstrated that the questionnaire effectively captured distinct signs associated with each seizure type, highlighting key differences between Types A and B (e.g., ability to walk, disorientation, response to owner's voice, autonomic signs, falling to the ground and body position [lying on the side]; Figure 5). Results of all explored seizure signs are presented in File S7. Based on the absolute differences in sign frequencies between Types A and B and their statistical significances calculated using Fisher's exact test, 17 items were chosen for further multivariable analyses. The items falling to the ground and body position (lying on the side during the episode) were subsequently excluded because these signs appeared in the description of Type A seizures. All responses with no missing values in any of the items of interest were included (339 Type A, 291 Type B).

The final model included the following four items: mouth opening ($p < 0.001$), overextension of the head and neck ($p < 0.001$), urination during the episode ($p < 0.001$), and ability to hear the owner during this type of episode (as interpreted by the owner; $p < 0.001$). The AUC value in the original model training cohort was 0.947. Assessing the model performance in the additional replication cohort resulted in an AUC value of 0.899 (File S3).

Generalized (epileptic) convulsive seizures (Type A) were often preceded by a focal onset in the minutes or seconds before the seizure began, with this focal onset reported in 73.9% (249/338) of Type A seizures. The focal onset manifested as motor signs in 59.8% (149/249), autonomic signs in 42.6% (106/249), or behavioral signs in 68.7% (171/249), either individually or in combination. Focal onset was consistently described in the detailed questions for 93.9% (234/249) of the seizures but only in the free-text section for 35.7% (89/249) of cases. A review of non-generalized paroxysmal motor episodes (Type B) revealed that 41.6% (121/291) showed signs consistent with dyskinesia based on published criteria (episode duration, awareness, no autonomic signs, no postictal changes); focal motor epileptic seizures were indicated in 51.5% (150/291), and 6.9% (20/291) remained undefined [10].

3.7 | Breed Differences

Labrador Retrievers displayed a different distribution of seizure types than Border Collies, Siberian Huskies, and the rest of the study cohort (χ^2: 35.09; df: 1; $p < 0.00001$) and were more likely to exhibit only one type of seizure or episode (χ^2: 11.19; df: 1; $p = 8.3 \times 10E{-}4$). Specifically, non-generalized motor episodes (Type B) were more common and occurred in 69.6% of the Labrador Retrievers, while generalized (epileptic) convulsive seizures (Type A) occurred less frequently in Labrador Retrievers than in the other dog breeds. Generalized (epileptic) convulsive seizures were the most common seizure type in Siberian Huskies (81.8%) and Border Collies (86.4%; χ^2: 28.64; df: 1; $p < 0.00001$; Figure 6).

In total, 69.6% (103/148) of the Labrador Retrievers experienced non-generalized motor episodes (Type B), with a median age at the onset of 2 years (IQR 1–3 years). Of these, a clinical review revealed that 69.9% (72/103) showed signs consistent with dyskinesia based on published criteria (episode duration, awareness, no autonomic signs, no postictal changes), while focal motor epileptic seizures were indicated in 24.3% (25/103), and 5.8% (6/103) remained undefined [10]. Six of the Labradors with Type B non-generalized motor episodes also had Type A seizures, characterized as generalized (epileptic) convulsive seizures with falling to the ground and convulsions. Of these, five showed additional episodes suggestive of focal epileptic seizures and one of dyskinesia. In 9.7% (7/72) of Labradors with signs of dyskinesia, unusual features were observed, including lip smacking, chewing movements, eyelid or facial twitches, salivation, vomiting at the onset, defecating after the episode (in two dogs), and dilated pupils. Owners frequently described the episodes as beginning from rest or sleep, often triggered by a sudden event or noise, such as a doorbell or barking.

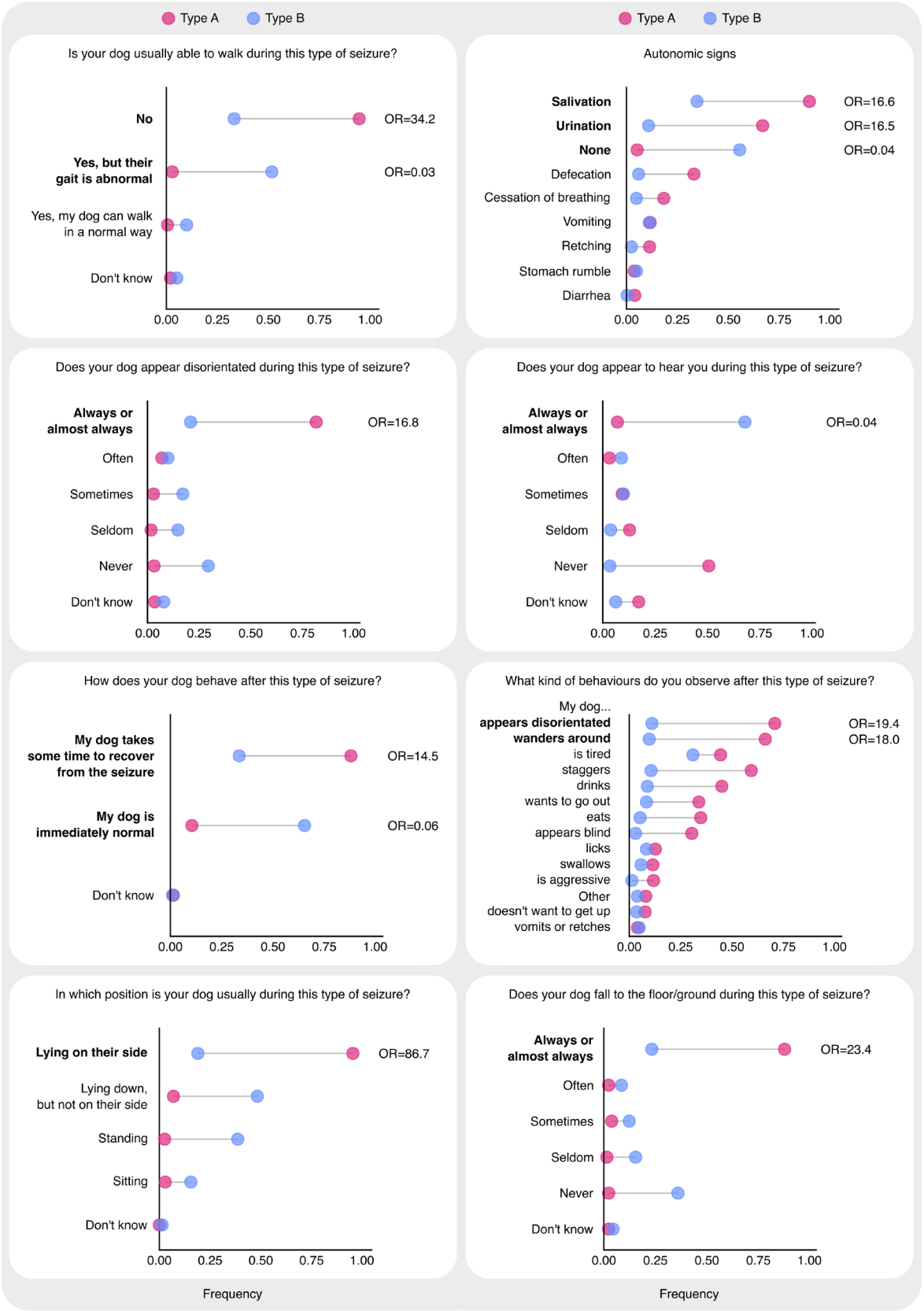

FIGURE 5 | Differences in signs between Type A seizures and Type B paroxysmal motor events. Falling and lying on the side were included in the description of Type A seizures.

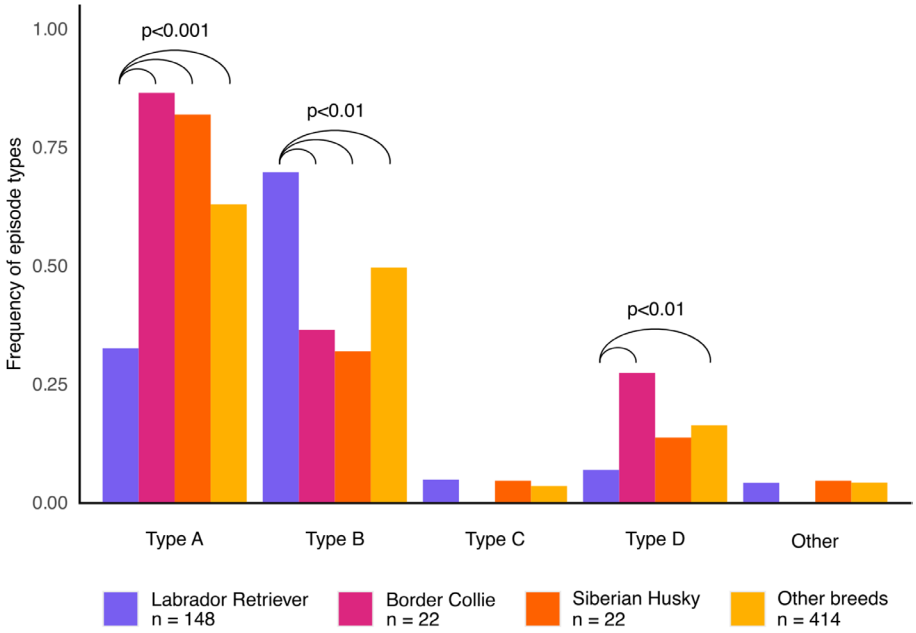

FIGURE 6 | Seizure type distribution for the most common breeds. Labrador Retrievers showed non-generalized motor events more frequently and a different seizure type distribution than other breeds ($p < 0.001$).

4 | Discussion

This study introduces a novel epilepsy and dyskinesia survey, demonstrating its effectiveness in capturing and describing various seizure types, dyskinesia episodes, and undefined paroxysmal events based on their motor, autonomic, and behavioral features. The survey's reliability was assessed in a sample comprising over 600 dogs, offering new insights into the distribution of generalized (epileptic) convulsive seizures and non-generalized paroxysmal events in the general dog population. A total of 606 dogs participated: 300 in the German language group, 131 in the English language group, and 175 in the Finnish language group. The median age of the dogs was 6 years (IQR 4–9 years), and the median age at first seizure was 2 years (IQR 1–5 years); 80% experienced their first seizure between 6 months and 6 years. More recently, additional datasets were contributed from Canada in French and English language (File S8).

The development of an intuitive and reliable survey is a significant advancement in harmonizing recruitment for large epidemiological and genetic studies, which are currently lacking. This new survey emerged from the need for a standardized online tool to produce comparable results across different cohorts and countries. Previous epilepsy questionnaires varied in content and structure, making it difficult to compare study populations [18–28]. To overcome these limitations and promote broader multinational collaborations, the survey was designed with specific scientific and technical objectives: an intuitive structure for comprehensive seizure phenotyping and classification, video tutorials for pragmatic observational classification, and user-friendly multilingual online access. This approach draws on the IVETF's suggestions and the team's previous success using example videos and detailed questions to identify specific seizure types in dogs, such as myoclonic seizures in genetic juvenile myoclonic epilepsy [36, 37]. It also aligns with the ILAE's focus on classifying seizures based on semiology and observable clinical signs.

The questionnaire featured a pragmatic seizure classification based on objective seizure semiology. The questionnaire featured a pragmatic seizure classification based on objective semiology. Owners first described each seizure type through free text, then reviewed video footage of different seizure types to identify the closest match, and finally, further described the seizures by answering detailed questions for each type. Another novel feature enabled owners to link questionnaire data with video footage of their dog's seizures and specify whether their dog experienced one or multiple seizure types with distinct semiologies. The paroxysmal events classified by the questionnaire included generalized convulsive (epileptic) seizures with motor signs (Type A), other paroxysmal motor events (Type B), sudden falls without movement resembling atonic seizures or drop attacks (Type C), episodes of impaired awareness (Type D), and other undefined episodes (Type E). In this study, owners reported seizure Type A in 58.6%, Type B in 58.1%, Type C in 6.1%, and Type D in 15.8% of cases, while 7.1% of dogs exhibited undefined episodes. A similar labeling approach, using letters to categorize seizure types and detailing each one, has also been used in epilepsy diaries for humans, such as labeling "A" for the most common and "B" for the second most common seizure type [38, 39]. This survey marks a crucial step in improving the standardization of data collection for canine epilepsy and dyskinesia, facilitating more comprehensive cross-country studies and laying the groundwork for future advances in both diagnosis and treatment.

Interestingly, this study identified non-generalized paroxysmal motor events as often as generalized tonic–clonic seizures in the general dog population. It is possible that providing video examples of different types of epileptic seizures, dyskinesia episodes, and other paroxysmal events encouraged greater reporting of non-generalized seizures. Underreporting of non-generalized

seizures has been a concern in veterinary medicine [40, 41]. Episodes where the dog appeared disoriented and unresponsive, summarized as Type D, are difficult to attribute to epileptic seizures without EEG confirmation. However, the suspicion of an epileptic origin increases when these episodes occur alongside generalized convulsive (epileptic) seizures, as seen in Figure 4. These episodes could represent typical or atypical absences, focal seizures with impaired awareness without observable signs, or non-epileptic episodes of abnormal behavior, including behavioral side effects of ASMs [42]. Despite this, the questionnaire successfully captured a broader range of paroxysmal events by prompting owners to report various seizure types.

Dog owners reported Type A seizures, corresponding to generalized convulsive (epileptic) seizures with motor signs (mostly tonic–clonic), in 58.6% of cases, while 41.4% involved other seizure types or episodes. Moreover, 25.2% of the dogs experienced multiple types of seizures or paroxysmal events, emphasizing the importance of documenting multiple seizure types for translational research. Multiple different seizure types occur in genetic myoclonic epilepsy in juvenile Rhodesian Ridgebacks, similar to juvenile myoclonic epilepsy in humans [37, 42, 43]. Multiple seizure types occur also in neurodegenerative diseases like Lafora disease and epileptic encephalopathies (e.g., Lennox–Gastaut syndrome [44], Dravet syndrome [15], epilepsy with myoclonic–atonic seizures [45]). Furthermore, paroxysmal movement disorders frequently co-occur in autoimmune, for example *N*-methyl-D-aspartate receptor (NMDAR) antibody encephalitis, leucine-rich glioma inactivated protein 1 (LGI1) antibody encephalitis [46], and genetic epilepsies for example *SCN2A, PRRT2* [14, 31].

The questionnaire included four supplementary sections covering history, veterinary examinations (including an upload link for a review of medical records), medication and diet, and behavior. These sections enabled a more comprehensive description of dogs with epilepsy or paroxysmal dyskinesia, including history, presumed etiology, diagnostic test results, and response to treatment, as is done in human medicine [11, 16, 47]. The section on veterinary examinations was essential for distinguishing between reactive seizures, structural brain lesions, and non-lesional epilepsy and for categorizing the level of diagnostic certainty for idiopathic epilepsy (i.e., Tier 1, Tier 2, or Tier 3), following IVETF guidelines [36]. Similarly, a tiered approach was applied to paroxysmal dyskinesia. Careful attention was given to include only dogs with recurrent seizures or episodes on 2 or more different days [1, 10]. No data cleaning was performed for structural epilepsy. Overall, blood examinations, neurological examinations, and brain imaging revealed abnormal findings in 9.0%, 8.0%, and 9.5%, respectively, when performed, and 15.5% of the dogs were older than 6 years when they experienced their first seizure or episode (Table 1).

Current clinical approaches in humans emphasize the initial classification of seizures and epilepsy based on seizure semiology with minimal reliance on technology (www.ilae.org) [16, 17, 47, 48]. Accordingly, the questionnaire provided detailed information on seizure onset, aiming to classify paroxysmal events by their onset as generalized, focal, or unknown onset. This approach aligns with ILAE guidelines that suggest a classification of epilepsies based on age of onset and seizure type, encouraging precise descriptions of motor, autonomic, or behavioral signs at the beginning of seizures [8]. Our data revealed that 73.9% of the generalized (epileptic) convulsive seizures (Type A) in the dogs showed focal motor or behavioral signs at the onset, classifying them as focal seizures with evolution to generalized seizures.

In comparing the signs associated with generalized (epileptic) convulsive seizures (Type A) with non-generalized paroxysmal motor episodes (Type B), Type A seizures were more frequently associated with urination, mouth opening, and overextension of the head and neck. Furthermore, Type A and Type B differed significantly in the ability to hear the owner during the episode. Type A and Type B differed also in the likelihood of falling to the ground and lying on the side, but these signs were also part of the description of Type A seizure and therefore not included in the multivariable analysis. In contrast, Type B events were characterized by responses indicating preserved awareness and fewer autonomic signs. Falls to the ground or the likelihood of falls were suggested as an additional descriptor for specific types of seizures or paroxysmal events in human medicine [17].

Internal consistency across different modes of seizure descriptions was notably strong for generalized (epileptic) convulsive seizures (Type A), other paroxysmal motor episodes (Type B), and episodes of impaired awareness without motor signs (Type D), demonstrating that the questionnaire is a robust tool. The agreement between video footage and seizure descriptions and the substantial interrater agreement among reviewers from different institutions and countries further support its reliability. Moderate agreement in the interpretation of Type D episodes in one reviewer group was due to discrepancies in rating subtle movements, such as eyelid twitches or the ability to walk during episodes [17, 42]. Lower reliability for Type C episodes was expected due to fewer distinct signs and fewer cases. Falls without movement resembling atonic seizures may overlap with falls during the tonic phase of generalized seizures. Type E episodes, which were difficult to categorize, showed the lowest reliability. To improve accuracy, owners could submit video footage of their dog's paroxysmal events. Overall, the dog owners' classifications were highly accurate, with 90.1% of cases aligning with the authors' interpretation of seizure type (A–E).

The questionnaire did not aim to distinguish between dyskinesia episodes and focal epileptic seizures but focused on precise and objective descriptions of seizure semiology. Both dyskinesia episodes and focal epileptic motor seizures are categorized as non-generalized paroxysmal motor events under the label Type B, acknowledging that distinguishing between the two can be challenging when based solely on clinical signs and assessment of awareness [1]. Recent studies suggested focal epilepsy with tonic ictal limb contractions in two dog breeds based on EEG data in a subgroup [49, 50]. The questionnaire's ability to capture a broad range of autonomic, motor, and behavioral signs in a standardized way, including questions targeting awareness, supports classifying episodic events based on semiology. EEG studies could further investigate the epileptic or non-epileptic origin of these events [36, 42, 51].

The questionnaire also proved valuable for comparing seizure semiology across breeds. Labrador Retrievers showed a

significantly different distribution of seizure types compared to Siberian Huskies, Border Collies, and the rest of the study cohort. Non-generalized paroxysmal motor events (Type B) occurred in 69.6% of the Labrador Retrievers, while generalized (epileptic) convulsive seizures were most common in Siberian Huskies (81.8%) and Border Collies (86.4%). Previous studies have reported paroxysmal dyskinesia in Labrador Retrievers [52]. Owners frequently described episodes starting from rest or sleep, often triggered by a sudden event or noise, such as a doorbell or barking, as described previously [52]. The appearance of specific seizure types with shared semiology and age of onset in a breed suggests a genetic predisposition.

The current study has highlighted opportunities to enhance the questionnaire by including additional questions that offer a deeper understanding of seizure semiology, for example, awareness and responsiveness, whether the dog's eyes are open or closed during an episode, distinguishing between collapsing and lying down during an episode, or confirming the semiology of atonic seizures. The study cohort was a sample from the general dog population with owner-reported epilepsy or dyskinesia. Some dogs may have had reactive seizures or structural epilepsy, and some dogs had onset beyond 6 years or lacked veterinary examinations. However, the mean age of onset was reflective of idiopathic epilepsy. A limitation was the absence of telephone interviews or on-site exams to confirm data and exclude epilepsy mimics. Reviewers did not provide their opinions on the epileptic or non-epileptic nature of the episodes. The translations were not systematically performed in both directions, which could result in inconsistencies or misunderstandings across languages. Lastly, since the survey is conducted online and targets large populations, continuous data curation is necessary.

In summary, this novel questionnaire supports pragmatic phenotyping of seizures and paroxysmal events in large cohorts of dogs with epilepsy or dyskinesia. It offers a reliable tool for characterizing epileptic seizures and dyskinesia episodes while uncovering breed-specific differences.

Acknowledgments

The study was partially funded by the American Kennel Club Canine Health Foundation (Hannes Lohi, Grant No: 2566, Tomas Parmentier, Fiona James, Andrea Fischer, Grant No: 03039), the Epilepsy Foundation (Tiina Harmas), the University of Helsinki DVM Doctoral Program (Tiina Harmas), the Jane and Aatos Erkko Foundation (Hannes Lohi), the Finnish Society of Science and Letters (Hannes Lohi) and the Agria Foundation (Hannes Lohi, Grant No.: N2022-0018). We thank Christopher Jenkins and Donna Foster, who contributed to helping translate the survey into English. We thank all the dog owners who participated in the survey.

Disclosure

Authors declare no off-label use of antimicrobials.

Ethics Statement

Approval of the institutional ethics committee of Ludwig-Maximilians-Universitat Munchen, Veterinary Faculty, 243-01-12-202. Authors declare human ethics approval was not needed.

Conflicts of Interest

Andrea Fischer receives sponsoring support from Purina Deutschland GmbH (Euskirchen, Germany) for the Ludwig-Maximilians-Universitat epilepsy consulting unit and from Vetoquinol GmbH (Ismaning, Germany) for the Ludwig-Maximilians-Universitat veterinary mobility center. Andrea Tipold serves as Associate Editor for the *Journal of Veterinary Internal Medicine*. She was not involved in the review of this manuscript. The other authors declare no conflicts of interest.

References

1. M. Berendt, R. G. Farquhar, P. J. J. Mandigers, et al., "International Veterinary Epilepsy Task Force Consensus Report on Epilepsy Definition, Classification and Terminology in Companion Animals," *BMC Veterinary Research* 11 (2015): 182.

2. M. Charalambous, A. Fischer, H. Potschka, et al., "Translational Veterinary Epilepsy: A Win-Win Situation for Human and Veterinary Neurology," *Veterinary Journal* 293 (2023): 105956.

3. P. J. Mandigers, K. M. Santifort, M. Lowrie, and L. Garosi, "Canine Paroxysmal Dyskinesia—A Review," *Frontiers in Veterinary Science* 11 (2024): 1441332.

4. M. Lowrie and L. Garosi, "Classification of Involuntary Movements in Dogs: Paroxysmal Dyskinesias," *Veterinary Journal* 220 (2017): 65–71.

5. L. Kearsley-Fleet, D. G. O'Neill, H. A. Volk, D. B. Church, and D. C. Brodbelt, "Prevalence and Risk Factors for Canine Epilepsy of Unknown Origin in the UK," *Veterinary Record* 172 (2013): 338.

6. A. Erlen, H. Potschka, H. A. Volk, et al., "Seizure Occurrence in Dogs Under Primary Veterinary Care in the UK: Prevalence and Risk Factors," *Journal of Veterinary Internal Medicine* 2018, no. 32 (2018): 1665–1676.

7. C. Tauber, "Epidemiologische Untersuchungen zum Vorkommen von Epilepsie bei Hund und Katze in der Kleintierpraxis" (dissertation, 130, LMU München, Tierärztliche Fakultät, 2017), last accessed September 20, 2024, https://edoc.ub.uni-muenchen.de/21050/1/Tauber_Clara-Antonia.pdf.

8. I. E. Scheffer, S. Berkovic, G. Capovilla, et al., "ILAE Classification of the Epilepsies: Position Paper of the ILAE Commission for Classification and Terminology," *Epilepsia* 58 (2017): 512–521.

9. R. S. Fisher, J. H. Cross, C. D'Souza, et al., "Instruction Manual for the ILAE 2017 Operational Classification of Seizure Types," *Epilepsia* 58 (2017): 531–532.

10. S. Cerda-Gonzalez, R. A. Packer, L. Garosi, et al., "International Veterinary Canine Dyskinesia Task Force ECVN Consensus Statement: Terminology and Classification," *Journal of Veterinary Internal Medicine* 35 (2021): 1218–1230.

11. E. C. Wirrell, R. Nabbout, I. E. Scheffer, et al., "Methodology for Classification and Definition of Epilepsy Syndromes With List of Syndromes: Report of the ILAE Task Force on Nosology and Definitions," *Epilepsia* 63 (2022): 1333–1348.

12. R. Erro, U. M. Sheerin, and K. P. Bhatia, "Paroxysmal Dyskinesias Revisited: A Review of 500 Genetically Proven Cases and a New Classification," *Movement Disorders* 29 (2014): 1108–1116.

13. ILAE Consortium on Complex Epilepsies, "GWAS Meta-Analysis of Over 29,000 People With Epilepsy Identifies 26 Risk Loci and Subtype-Specific Genetic Architecture," *Nature Genetics* 55 (2023): 1471–1482.

14. C. von Stülpnagel, A. Van Baalen, I. Borggraefe, et al., "Network for Therapy in Rare Epilepsies (NETRE): Lessons From the Past 15 Years," *Frontiers in Neurology* 11 (2021): 622510.

15. S. M. Zuberi, E. Wirrell, E. Yozawitz, et al., "ILAE Classification and Definition of Epilepsy Syndromes With Onset in Neonates and Infants: Position Statement by the ILAE Task Force on Nosology and Definitions," *Epilepsia* 63 (2022): 1349–1397.

16. N. A. Shlobin, G. Singh, C. R. Newton, and J. W. Sander, "Classifying Epilepsy Pragmatically: Past, Present, and Future," *Journal of the Neurological Sciences* 427 (2021): 117515.

17. C. Steriade, M. R. Sperling, B. DiVentura, et al., "Proposal for an Updated Seizure Classification Framework in Clinical Trials," *Epilepsia* 63 (2022): 565–572.

18. E. E. Patterson, J. R. Mickelson, Y. Da, et al., "Clinical Characteristics and Inheritance of Idiopathic Epilepsy in Vizslas," *Journal of Veterinary Internal Medicine* 17 (2003): 319–325.

19. E. E. Patterson, P. J. Armstrong, D. P. O'Brien, M. C. Roberts, G. S. Johnson, and J. R. Mickelson, "Clinical Description and Mode of Inheritance of Idiopathic Epilepsy in English Springer Spaniels," *Journal of the American Veterinary Medical Association* 226 (2005): 54–58.

20. M. Berendt, C. H. Gulløv, S. L. K. Christensen, et al., "Prevalence and Characteristics of Epilepsy in the Belgian Shepherd Variants Groenendael and Tervueren Born in Denmark 1995-2004," *Acta Veterinaria Scandinavica* 50 (2008): 51.

21. C. H. Gulløv, N. Toft, M. M. N. Baadsager, and M. Berendt, "Epilepsy in the Petit Basset Griffon Vendeen: Prevalence, Semiology, and Clinical Phenotype," *Journal of Veterinary Internal Medicine* 25 (2011): 1372–1378.

22. K. M. Santifort, E. Bertijn, S. F. M. Bhatti, et al., "Phenotypic Characterization of Idiopathic Epilepsy in Border Collies," *Frontiers in Veterinary Science* 9 (2022): 880318.

23. T. E. Ostermann, J. N. Nessler, H. Urankar, et al., "Phenotype of Idiopathic Epilepsy in Great Swiss Mountain Dogs in Germany—A Retrospective Study," *Frontiers in Veterinary Science* 9 (2022): 921134.

24. V. Hülsmeyer, R. Zimmermann, C. Brauer, C. Sauter-Louis, and A. Fischer, "Epilepsy in Border Collies: Clinical Manifestation, Outcome, and Mode of Inheritance," *Journal of Veterinary Internal Medicine* 24 (2010): 171–178.

25. L. De Risio, R. Newton, J. Freeman, et al., "Idiopathic Epilepsy in the Italian Spinone in the United Kingdom: Prevalence, Clinical Characteristics, and Predictors of Survival and Seizure Remission," *Journal of Veterinary Internal Medicine* 29 (2015): 917–924.

26. M. Plonek, M. M. Diaz-Espineira, Q. Stassen, et al., "Phenotypic Characterization of Idiopathic Epilepsy and Epilepsy of Unknown Cause in Irish Setters," *Frontiers in Veterinary Science* 9 (2022): 1066094, https://doi.org/10.3389/fvets.2022.1066094.

27. N. Kinsey, J. M. Belanger, P. J. J. Mandigers, et al., "Idiopathic Epilepsy Risk Allele Trends in Belgian Tervuren: A Longitudinal Genetic Analysis," *Genes* 15, no. 1 (2024): 114, https://doi.org/10.3390/genes15010114.

28. T. Deschain, J. Fabricius, M. Berendt, M. Fredholm, and P. Karlskov-Mortensen, "The First Genome-Wide Association Study Concerning Idiopathic Epilepsy in Petit Basset Griffon Vendeen," *Animal Genetics* 52 (2021): 762–766.

29. P. J. J. Mandigers, F. G. Van Steenbeek, W. Bergmann, et al., "A Knockout Mutation Associated With Juvenile Paroxysmal Dyskinesia in Markiesje Dogs Indicates SOD1 Pleiotropy," *Human Genetics* 140 (2021): 1547–1552.

30. J. Nessler, P. Hug, P. J. Mandigers, et al., "Mitochondrial PCK2 Missense Variant in Shetland Sheepdogs With Paroxysmal Exercise-Induced Dyskinesia (PED)," *Genes* 11, no. 7 (2020): 774, https://doi.org/10.3390/genes11070774.

31. A. Papandreou, F. R. Danti, R. Spaull, V. Leuzzi, A. Mctague, and M. A. Kurian, "The Expanding Spectrum of Movement Disorders in Genetic Epilepsies," *Developmental Medicine and Child Neurology* 62 (2020): 178–191.

32. B. P. Koeleman, "What Do Genetic Studies Tell Us About the Heritable Basis of Common Epilepsy? Polygenic or Complex Epilepsy?," *Neuroscience Letters* 667 (2018): 10–16.

33. P. Perucca, M. Bahlo, and S. F. Berkovic, "The Genetics of Epilepsy," *Annual Review of Genomics and Human Genetics* 21 (2020): 205–230.

34. J. E. Motelow, G. Povysil, R. S. Dhindsa, et al., "Sub-Genic Intolerance, ClinVar, and the Epilepsies: A Whole-Exome Sequencing Study of 29,165 Individuals," *American Journal of Human Genetics* 108 (2021): 965–982.

35. E. Beckers, S. F. Bhatti, M. Van Poucke, et al., "Identification of a Novel Idiopathic Epilepsy Risk Locus and a Variant in the CCDC85A Gene in the Dutch Partridge Dog," *Animals* 13, no. 5 (2023): 810, https://doi.org/10.3390/ani13050810.

36. L. De Risio, S. Bhatti, K. Muñana, et al., "International Veterinary Epilepsy Task Force Consensus Proposal: Diagnostic Approach to Epilepsy in Dogs," *BMC Veterinary Research* 11 (2015): 148.

37. F. Wielaender, R. Sarviaho, F. James, et al., "Generalized Myoclonic Epilepsy With Photosensitivity in Juvenile Dogs Caused by a Defective DIRAS Family GTPase 1," *Proceedings of the National Academy of Sciences of the United States of America* 114 (2017): 2669–2674.

38. Epilepsy Foundation, "My Seizure Calender," accessed September 20, 2024, https://www.epilepsy.com/sites/default/files/atoms/files/720MSC_MySeizureCalendar_05-2019.pdf.

39. Schweizerische Epilepsieliga, "Anfallskalender," accessed September 20, 2024, https://www.epi.ch/wp-content/uploads/epilepsie_liga_anfallskalender_D_2016_summenberechnung.pdf.

40. M. Ukai, T. Parmentier, M. A. Cortez, et al., "Seizure Frequency Discrepancy Between Subjective and Objective Ictal Electroencephalography Data in Dogs," *Journal of Veterinary Internal Medicine* 35, no. 4 (2021): 1819–1825, https://doi.org/10.1111/jvim.16158.

41. C. Tästensen, S. Gutmann, S. Loderstedt, et al., "Prevalence of Nonconvulsive Seizures and Nonconvulsive Status Epilepticus in Dogs and Cats With a History of Cluster Seizures: A Retrospective Study," *Journal of Veterinary Internal Medicine* 3 (2024): 238–246.

42. F. Wielaender, F. M. K. James, M. A. Cortez, et al., "Absence Seizures as a Feature of Juvenile Myoclonic Epilepsy in Rhodesian Ridgeback Dogs," *Journal of Veterinary Internal Medicine* 32 (2018): 428–432.

43. E. Hirsch, J. French, I. E. Scheffer, et al., "ILAE Definition of the Idiopathic Generalized Epilepsy Syndromes: Position Statement by the ILAE Task Force on Nosology and Definitions," *Epilepsia* 63, no. 6 (2022): 1475–1499, https://doi.org/10.1111/epi.17236.

44. A. Strzelczyk, S. M. Zuberi, P. Striano, F. Rosenow, and S. Schubert-Bast, "The Burden of Illness in Lennox–Gastaut Syndrome: A Systematic Literature Review," *Orphanet Journal of Rare Diseases* 18, no. 1 (2023): 42.

45. N. Specchio, E. C. Wirrell, I. E. Scheffer, et al., "International League Against Epilepsy Classification and Definition of Epilepsy Syndromes With Onset in Childhood: Position Paper by the ILAE Task Force on Nosology and Definitions," *Epilepsia* 63, no. 6 (2022): 1398–1442, https://doi.org/10.1111/epi.17241.

46. B. Balint, A. Vincent, H. M. Meinck, S. R. Irani, and K. P. Bhatia, "Movement Disorders With Neuronal Antibodies: Syndromic Approach, Genetic Parallels and Pathophysiology," *Brain* 141, no. 1 (2018): 13–36, https://doi.org/10.1093/brain/awx189.

47. T. Loddenkemper, C. Kellinghaus, E. Wyllie, et al., "A Proposal for a Five-Dimensional Patient-Oriented Epilepsy Classification," *Epileptic Disorders* 7 (2005): 308–316.

48. S. T. Sarmast, A. M. Abdullahi, and N. Jahan, "Current Classification of Seizures and Epilepsies: Scope, Limitations and Recommendations for Future Action," *Cureus* 12 (2020): e10549.

49. Y. Yu, D. Hasegawa, S. Kanazono, et al., "Clinical Characterization of Epileptic Seizures in Pomeranians With Idiopathic Epilepsy or Epilepsy of Unknown Cause," *Journal of Veterinary Internal Medicine* 36 (2022): 2013–2122.

50. F. C. Pellegrino, C. Blanco, and O. A. Martínez, "Epilepsia idiopatica focal con crisis motoras en 50 caniches en Argentina: caracterizacion electroclinica y respuesta a la terapia," *Anales de Veterinaria de Murcia* 38 (2024): 1–27.

51. E. Chawner, M. Ukai, W. Sears, et al., "Frequency of Non-generalized Tonic-Clonic Seizures in a Referral Population of Dogs," *Veterinary Journal* 295 (2023): 10598.

52. M. Lowrie and L. Garosi, "Natural History of Canine Paroxysmal Movement Disorders in Labrador Retrievers and Jack Russell Terriers," *Veterinary Journal* 213 (2016): 33–37.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.