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Daily Controlled Physiotherapy Increases Survival Time in Dogs with Suspected Degenerative Myelopathy

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The purposes of the study reported here were to evaluate the signalment and clinical presentation in 50 dogs with degenerative myelopathy, to evaluate whether mean survival time was significantly affected by various means of physiotherapy performed in 22 dogs, and to determine whether neurologic status, anatomic localization, or age at onset had an influence on survival time in dogs that received physiotherapy. We found a significant ($P < .05$) breed predisposition for the German Shepherd Dog, Kuvasz, Hovawart, and Bernese Mountain Dog. Mean age at diagnosis was 9.1 years, and both sexes were affected equally. The anatomic localization of the lesion was spinal cord segment T3–L3 in 56% (n = 28) and L3–S3 in 44% (n = 22) of the dogs. Animals that received intensive (n = 9) physiotherapy had longer ($P < .05$) survival time (mean 255 days), compared with that for animals with moderate (n = 6; mean 130 days) or no (n = 7; mean 55 days) physiotherapy. In addition, our results indicate that affected dogs which received physiotherapy remained ambulatory longer than did animals that did not receive physical treatment.

Key words: Breeds; Clinical signs; Degenerative spinal cord disease; Effectiveness; Physiotherapeutic protocol.

Degenerative myelopathy (DM) in dogs was 1st described by Averill in 1973[1] as a specific degenerative neurologic disease of the spinal cord. Other terms used were chronic degenerative radiculomyelopathy,[2] German Shepherd Dog myelopathy,[3] and progressive myelopathy.[4,5] The reported age at onset was 5 to 14 years, sex predilection was not observed, and German Shepherd Dogs seemed to be overrepresented.[1,2,6–8] The disease is usually slowly progressive, starting with truncal ataxia in the pelvic limbs and leading to severe weakness in the hind limbs. Initially, affected dogs may manifest knuckling over of the toes, wearing of the nails, and stumbling. In most dogs, clinical signs of disease are consistent with a lesion in the upper motor neuron (UMN) system that is characterized by exaggerated spinal reflexes and proprioceptive deficits as well as increased muscle tone.[1,3] Less frequently, decreased spinal reflexes and muscle tone in the pelvic limbs have been described.[2,8] Antemortem diagnosis of DM is based on signalment (older large-breed dogs), onset of clinical signs of disease (slow progression), and diagnostic evaluation, including plain radiography, cerebrospinal fluid (CSF) analysis, myelography, computed tomography (CT), and magnetic resonance imaging (MRI), to exclude other spinal cord diseases. Histologic examination confirms the diagnosis and identifies demyelination and axonal degeneration in the spinal cord that is most prominent in the dorsolateral white matter. In dogs with advanced DM, degenerative changes are observed in the lumbar dorsal nerve roots.[1–3] Recently, study of the brain of DM-affected dogs revealed neuronal degeneration and loss in the red nucleus, lateral vestibular nucleus, and dendate nucleus; these changes may be related to the origin of damage and subsequent Wallerian degeneration.[8]

The cause of DM is still unknown. Several controversial hypotheses, such as vitamin B complex or vitamin E deficiency, have been discussed by various authors.[1,2,9–11] In the late 1980s, DM was suspected to be an immune-mediated disease.[4,5,12,13] Later, the theory of a dying-back neuropathy was rejected by some authors.[1,2] A genetic component was proposed by the same authors because of overrepresentation of the German Shepherd Dog breed.[3]

Specific therapy does not exist. Recently, it has been suggested that physiotherapy may allow a good quality of life for a long period in dogs with DM.[14,15] However, to the authors' knowledge, clinical trials in a larger population of dogs with DM so far have not been undertaken.

The objectives of the retrospective study reported here were: to describe the breed distribution, age at onset, and sex of affected dogs, and the clinical presentation of DM in 50 dogs; to evaluate whether mean survival time in 22 dogs with DM, for which follow-up was available, was significantly affected by physiotherapy; and to evaluate whether survival time was influenced by neurologic status, anatomic localization of the lesion, or age at onset.

Materials and Methods

The clinical records of dogs with DM were analyzed retrospectively. All had been referred to the Department of Clinical Veterinary Medicine, Section of Neurology of the University of Berne, between August 1989 and February 2003. Fifty dogs fulfilled the following criteria to be included in the study: middle-aged to older large-breed dogs or mixed-breed dogs weighing >20 kg; history of slowly progressive course of disease; neurologic examination (evaluation of posture, gait, spinal reflexes, postural

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Table 1. Prescribed physiotherapy for dogs with degenerative myelopathy (DM).

	Instructions	Duration and frequency
Active exercise	• Slow walking • If needed, knuckling is prevented by a sling around the paw and pulling the dog's limb by each step with it • Frequent exercises preferred to long exercises • Exercise has to be adapted to animal's condition • Dog sits and gets up several times • Assistance with a sling if needed • Attention is paid to correct placement of the paws • Weight shifting while standing: making the dog bear his weight once on the left, then on the right side by pushing him gently at the level of the hip • Changing of ground (grass, asphalt, sand) • Stair climbing, walking uphill	5–10 minutes at least 5 times/d
Passive exercise	• Gentle, slow extension and flexion of each joint of both hind limbs (starting distally, manipulating of each joint performed separately) • Maintaining the range of physiologic motion of each joint • The limb is always fixed proximally to the joint and the distal part is moved	3 times/d, 10 times in each articulation
Massage	• Massage is started and finished with stroking • Gentle massage (kneading) of the entire paravertebral muscles and the limbs, starting from distal to proximal	3 times/d
Hydrotherapy	• If available, walking on underwater treadmill; otherwise, swimming or walking in water, depending on dog's ability • Adaptation to animal's condition is important • Assistance with a sling as needed • Weight shifting while standing in water: making the dog bear its weight once on the left, then on the right by pushing him gently at the level of the hip	At least once a week, 5–20 minutes
Paw protection	• With a bandage or socks and shoes	While walking

reactions, and cranial nerves); confirmation of paraparesis and ataxia in the hind limbs in the absence of spinal hyperesthesia on palpation; and normal results of diagnostic imaging (myelography [n = 48], CT [n = 1], or MRI [n = 1]). Orthopedic examination was performed on all dogs, and radiography was performed on dogs with concurrent orthopedic diseases. In addition, the following examinations were performed in selected instances: hematologic analysis (n = 47), serum biochemical analysis (n = 47), urinalysis (n = 10), and thoracic radiography (n = 19), the results of which were normal. Analysis of CSF was performed in 44 dogs (occipital [n = 43] and lumbar [n = 1] sites of collection).

Electromyography of all 4 limbs and the paravertebral muscles was performed in 23 dogs, and nerve conduction velocity of the peroneal nerve was conducted in 10 dogs. The diagnosis of DM was based mainly on history (chronic progressive ataxia and paraparesis without spinal hyperesthesia), age (older dogs), and exclusion of other spinal cord disease (normal myelographic, CT, or MRI results). In 4 dogs (1 mixed-breed dog, 1 Kuvasz, 1 German Shepherd Dog, and 1 Hovawart), the diagnosis was confirmed by histologic examination.

To document predilection of DM in certain breeds, the breed distribution of the dog population seen at our clinic over the last 10 years was compared with that of the 50 dogs with DM. Only those breeds for which 4 or more individuals were present in our study (ie, Bernese Mountain Dog, German Shepherd Dog, Hovawart, and Kuvasz) were kept as separate groups; all other breeds were pooled into 1 group that formed the baseline for comparison.

All owners received careful instruction on how to perform adequate physiotherapy following a study protocol. Suggested physiotherapy included gait exercise, massage, passive joint movement, and hydrotherapy, as described by Jaggy and Kathmann.[14] Briefly, active exercise was prescribed as short walks of 5–20 minutes (depending on the dog's neurologic status), 5 times daily. If necessary, dogs were supported with a sling; special attention was paid to correct placement of the paws while walking and standing. Daily massage of hind limb and spinal muscles and gentle passive joint movement (performed 10 times separately in the hip, stifle, and tarsal and digital joints) was applied 3 times per day. Hydrotherapy (swimming or water treadmill if available) was performed at least once per week for 5–20 minutes, depending on the dog's condition. Protection of the paws was provided by bandages or socks when necessary (Table 1).

All owners were interviewed by telephone to obtain follow-up information (Fig 1). Special emphasis was placed on time between diagnosis and euthanasia (ie, survival time) as well as intensity of the physiotherapy that was performed. The dogs with follow-up information were classified into 3 groups according to the intensity of physiotherapy performed (1 = intensive, 2 = moderate, 3 = none). Group 1 included dogs that received intensive physiotherapy (ie, gait exercise at least 3–5 times/d, additionally either massage and passive joint movement 3 times/d or daily hydrotherapy). Group-2 dogs received moderate physiotherapy (ie, gait exercise maximally 3 times/d and hydrotherapy or massage once a week). Physiotherapy was not performed on group-3 dogs.

To assess the neurologic status of patients with follow-up information, dogs were classified into 3 groups according to the degree of neurologic deficits (ie, mild, moderate, severe) at the time of diagnosis. The degree was characterized by severity of ataxia and paraparesis in the hind limbs of the rested animal. The 1st group had mild paraparesis and ataxia, which was more evident during change of direction or running. The 2nd group included dogs with moderate ataxia and paraparesis in the hind limbs that was characterized by intermittent knuckling of the toes. The 3rd and

When did your dog die or when was it euthanized?
What was the reason for euthanasia?
Was your dog able to ambulate at time of euthanasia?
Was your dog able to stand up without assistance?
Walk with assistance or without?
Was there any fecal or urinary incontinence?
Were the front limbs also affected?
How long before euthanasia had the dog been non-ambulatory?
What kind of exercises/physiotherapeutic method was performed, for how long, and at which frequency?

- Did you do gait exercise and how (duration and frequency)?
- Did you do massage and how (duration and frequency)?
- Did you do passive joint movement and how (duration and frequency)?
- Did the dog swim or walk on an underwater treadmill and how (duration and frequency)?
- Were the paws protected and how?

Fig 1. Questionnaire used for telephone interview.

worst-affected group had severe ataxia and paraparesis, with spontaneous knuckling of the toes and frequent falling while walking.

The variables breed, age, sex, weight, and onset and course of clinical signs of disease, as well as the neurologic status at time of presentation were evaluated descriptively and were tested for their association with the recorded days of survival by means of one-way ANOVA, Kaplan-Meier survival plots, and Cox regression. Surviving dogs were censored in the survival analysis. Days surviving was related to the variables age at diagnosis and anatomic localization of the lesion T3–L3 (3rd thoracic spinal cord segment to 3rd lumbar spinal cord segment) or L3–S3 (3rd lumbar spinal cord segment to 3rd sacral spinal cord segments, including nerve roots). All data were analyzed with the software package Number Cruncher Statistical System (NCSS).[16] The level of statistical significance was $P < .05$.[a]

Results

Affected breeds among the 50 dogs with DM included German Shepherd Dog (13; 26%), mixed-breed dog (13; 26%), Hovawart (7; 14%), Bernese Mountain Dog (4; 8%), Kuvasz (4; 8%), Collie (3; 6%), Belgian Shepherd (1; 2%), Giant Schnauzer (1; 2%), Labrador Retriever (1; 2%), Borzoi (1; 2%), Soft-coated Wheaten Terrier (1; 2%), and Mastiff (1; 2%). Significantly ($P < .05$) overrepresented breeds included Kuvasz, Hovawart, German Shepherd Dog, and Bernese Mountain Dog (Table 2). Mean age at onset was 9.1 years (range, 6–13 years). Twenty-eight male (castrated: n = 2) and 22 female (spayed: n = 11) dogs were affected. A sex predilection was not found.

The neurologic examination identified paraparesis, ataxia, and proprioceptive deficits in both pelvic limbs in all dogs. Lateralization of the neurologic deficits was seen in almost half of the dogs (n = 26). Wearing of the nails was seen in 20 dogs, and hypermetria of the pelvic limbs was evident in 11 dogs. Twenty-two dogs (44%) had signs of lower motor neuron (LMN) dysfunction, including decreased patellar (n = 18) or flexor (n = 18) reflexes in either one (n = 3) or both (n = 19) hind limbs, as well as decreased cranial tibial reflex in 7 dogs. Signs of UMN dysfunction were found in 28 (56%) dogs with increased patellar (n = 9) or cranial tibial (n = 4) reflex, or normal reflexes (n = 17), as well as decreased panniculus reflex (n = 6). Results of myelography, CT, or MRI performed in all dogs were normal. Dogs with myelographic results suspicious for mild disk protrusion were not included in the study. Suspicion of clinical relevance was raised when ventral contrast columns were interrupted or thinned over the disk protrusion, or if deviation of the contrast columns was observed on the lateral or ventrodorsal view. Results of CSF examination were abnormal in 2 dogs (slightly increased protein content [ie, Pandy positive] in both dogs with normal cell count). Electromyography identified mild fibrillation potentials of distal extensor and flexor muscles in 2 dogs with signs of LMN dysfunction. Motor nerve conduction velocity was normal in 10 dogs, including the 2 dogs with abnormal electromyographic findings. In 4 dogs, concurrent hip dysplasia was present in addition to DM. The orthopedic diagnosis was based on clinical (ie, painful hip extension and abduction) and radiographic (ie, osteoarthrotic alterations in the hips) findings. In 22 of the 50 dogs for which follow-up data were available, survival time ranged between 2 weeks and 1 year. In all 22 dogs with follow-up data, DM had been diagnosed between 1998 and 2003. At the time of euthanasia, all dogs (n = 22) were nonambulatory and paraplegic. In 6 dogs, paraparesis was accompanied by urinary and fecal incontinence. Mean survival time was 255 (SD 99.4) days in dogs that received intensive physiotherapy (n =

Table 2. Breed distribution of dogs with DM.

Breed	No. dogs with DM	No. dogs in the entire clinic population over the past 10 years	Fisher's exact test (*P*-value)	Odds ratio (95% CI)
Mixed breed and others	22	3,903		1 (Reference)
Bernese Mountain Dog	4	195	.034	4 (1.44–11.10)
German Shepherd Dog	13	470	< .0001	5 (2.52–9.84)
Hovawart	7	29	< .0001	44.1 (17.9–108.7)
Kuvasz	4	11	< .0001	67.9 (21.2–217.8)
Total No. dogs	50	4,608		

CI, confidence interval.

9). Dogs that received moderate physiotherapy (n = 6) had mean survival time of 130 (SD 31.0) days, and those that did not receive physiotherapy (n = 7) had mean survival time of 55 (SD 31) days (Fig 2). Of 22 dogs with follow-up data, neurologic deficits were mild in 6, moderate in 7, and severe in 9 dogs at the time of diagnosis. For further analysis, however, data for the moderate and severe groups were combined.

In the Cox regression, univariable associations between survival time and the factors degree of neurologic deficits, age, weight, sex and neuter status, breed, and localization were not found ($P > .10$). Compared with values for the group with intensive physiotherapy, the risk of dying, after adjusting for the initial degree of neurologic deficits, was 5.8 times higher ($P = .046$) for dogs with moderate physiotherapy and was 112 times higher ($P < .001$) for dogs without physiotherapy (Fig 3).

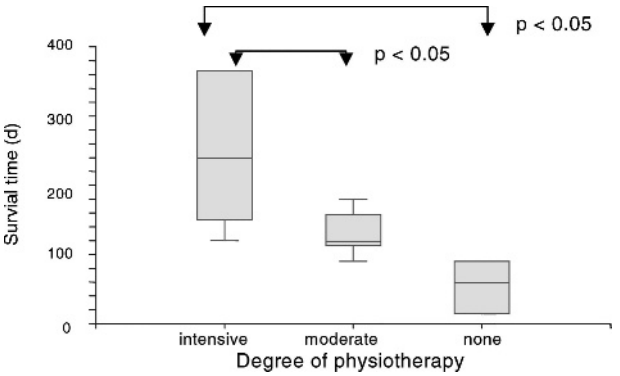

Fig 2. Box-and-whisker plot: x-axis, degree of physiotherapy; y-axis, survival time in days (d). Dogs receiving intensive (group 1) physiotherapy survived significantly ($P < .05$) longer than did dogs with moderate (group 2) or no (group 3) physiotherapy.

Discussion

The 1st objective of the study was to describe the signalment and clinical presentation of DM. The 2nd goal was to determine whether mean survival time was correlated with different degrees of physiotherapy and to determine whether survival time was influenced by neurologic status, anatomic localization of the lesion, or age at onset of DM.

Although DM has been described in a Miniature Poodle and in Pembroke Welsh Corgies, the disease seems to affect predominantly large-breed dogs, especially German Shepherd Dogs.[1–3,8,17–19] In addition to the German Shepherd Dog, we found the Bernese Mountain Dog, the Kuvasz, and the Hovawart to be at significantly higher risk ($P < .05$). So far, predisposition for DM has not been described for these breeds. An inherited basis for DM in these breeds, including the Kuvasz, is suspected.

Age at onset, sex distribution, and clinical signs of disease in these 50 dogs were comparable to those identified in previous studies.[1–3,6–8,17,20] In contrast to the literature, however, we did not find a difference between number of dogs (n = 28; 56%) with UMN (T3–L3) and number of dogs (n = 22; 44%) with LMN (L3–S3) disease.[1,2,12] Some authors have suggested that decreased spinal reflexes in dogs with DM may be caused by degeneration of dorsal nerve root fibers or pathologic changes in the lumbar part of the spinal cord, especially the dorsolateral columns.[2,8,12]

The diagnosis of DM is based on a history of chronic progressive ataxia and pelvic limb paresis without signs of spinal pain in older dogs.[1–3,8,12,13] Myelography usually does not reveal signs of compression or intramedullary spinal cord swelling. However, minor disk protrusions, spondylosis deformans, or osseous dural metaplasia frequently are found in older dogs, complicating the diagnosis of DM.[12,13] Many dogs also have signs of orthopedic diseases such as hip dysplasia, further complicating diagnosis.[12,13] Results of CSF analysis are normal in most instances, but can indicate increased protein concentration, especially when samples are collected from the lumbar site. Electromyographic findings usually are normal, except in patients with LMN involvement.[12] Electromyographic examination was performed in 17 of 22 dogs with signs of LMN dysfunction. Abnormalities were found in 2 dogs. This low incidence of EMG abnormalities might be explained by degenerative changes in the gray and white matter of the lumbar spinal cord, but this suspicion requires histopathologic confirmation.[2,8,12]

Similar to that of other degenerative central nervous system diseases, the diagnosis of DM is confirmed histologically. In our study, 4 dogs had postmortem examination, and in the remaining dogs, diagnosis was based on exclusion of other spinal cord diseases. Therefore, in most of these dogs, definitive diagnosis remained elusive although all of them fulfilled rigid inclusion criteria for the antemortem diagnosis of DM. In the author's (I.K.) experience, DM is beyond the detection capabilities of low- or high-field MRI scanning, including contrast studies. Therefore, we believe that adding MRI would not have changed the final diagnosis and management of the dogs. In 22 of the 50 dogs, follow-up information was available and confirmed the characteristic progression of pain-free spinal cord disease. This natural course of DM provides further support to the diagnosis of DM.[1–3,8,12,13]

The high incidence of LMN lesions in this series suggests that this form of DM may be more common than was previously believed.[1,2,12] However, this finding must be interpreted with caution. Older dogs may have decreased patellar reflexes without neurologic impairment, and severe muscle wasting may result in decreased muscle strength and reduced withdrawal reflexes.[21] On the other hand, spinal ataxia and proprioceptive deficits were the most obvious neurologic deficits in all of our dogs including those with signs of LMN dysfunction. Sensory polyneuropathy of unknown origin would have been the only reasonable alternative to the diagnosis of DM in our dogs. Sensory polyneuropathies in dogs usually are age and breed related.[22] Furthermore, the most likely origin of ataxia in our dogs was in the white matter of the spinal cord, not in the peripheral nervous system. Nevertheless, more detailed electrodiagnostic

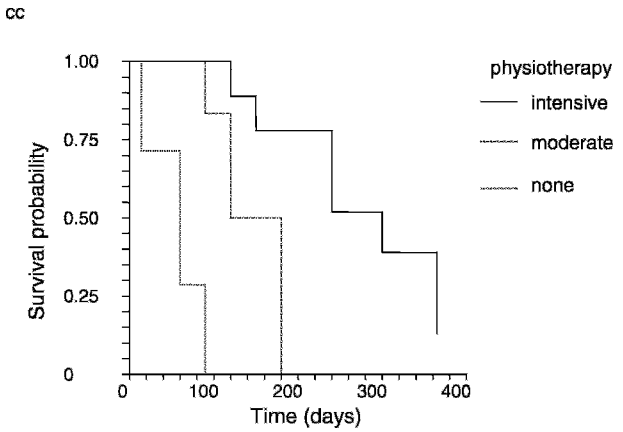

Fig 3. Kaplan-Meier plots for survival probability over time (in days) of dogs receiving intensive (group 1), moderate (group 2), or no (group 3) physiotherapy. The differences for the "no therapy" group were statistically significant (Cox regression model; $P < .05$).

testing, including motor and sensory nerve conduction evaluation, nerve and muscle biopsies, and histologic examination of the spinal cord, are necessary to definitely substantiate the true incidence of the LMN form of DM.

Degenerative myelopathy is a slowly progressive, degenerative disease of the spinal cord in older large-breed dogs that inevitably results in nonambulatory paraparesis.[1–3,8,12,13] So far and to our knowledge, no clinical study has identified an effective treatment. A combination of exercise, vitamin support (vitamin B complex and vitamin E), aminocaproic acid, and N-acetylcysteine has been proposed, and use of prednisone also has been suggested.[12,13,23] In 2001, we proposed that physiotherapy may positively influence the course of the disease.[15] In human medicine, it has been clearly documented that physiotherapy in the treatment of chronic multiple sclerosis (a neurodegenerative disorder similar to DM in dogs with regard to its chronic progressive course) is associated with improved mobility, subjective well-being, and improved mood.[24] Several authors suggested that exercise and physiotherapy are important to slow the progression of DM, but a controlled study was not available to document efficacy.[12,13,15,23] Results of the study reported here indicate that daily, controlled physiotherapy prolongs ($P < .05$) survival time of affected dogs up to an average of 255 days. A physiotherapy protocol, including daily gait exercise, massage, passive joint movement, and hydrotherapy, seemed to be the most important factors in preserving ambulatory status in dogs with DM.

We acknowledge 3 limitations of this report. First, histologic examination was not performed in all dogs and a definitive diagnosis of DM cannot be established with certainty in all dogs. Secondly, final neurologic examination findings were not available and owner compliance could not be controlled. However, all animals were nonambulatory and paraplegic at the time of euthanasia, and this outcome was the reason for euthanasia of all affected dogs. Third, the study was not randomized and dog owners could have been biased because they all were pursuing time-consuming and intensive therapy for their animals. It is possible that daily observation of their pet and a strong human-animal bond may have masked true appraisal of the effect of physiotherapy. Animals are not considered sensitive to placebo effects, but pet owners may be influenced. A positive perception of any treatment form can positively influence its results. We tried to overcome this methodologic weakness by including only dogs with a known time course (onset until end stage) of their disease. This objective variable allowed comparison among groups.

Considering the results of this study, survival time was positively associated with the degree of physiotherapy. Simultaneously, mean survival time and degree of physiotherapy performed were similar in the groups categorized by the severity of neurologic deficits at the time of diagnosis. This finding suggests that, even in dogs with severe neurologic deficits at time of diagnosis, physiotherapy may result in longer survival time even in comparison with that of dogs with minor neurologic deficits that did not receive physiotherapy. The degree of neurologic deficits and age did not seem to influence owner compliance because significant difference in age was not found among groups with different levels of physiotherapy.

The decision-making process for the veterinary neurologist is difficult when facing neurodegenerative disease of the spinal cord. Diagnosis rarely can be confirmed without an invasive, expensive, and potentially harmful biopsy procedure. The diagnosis remains presumptive after the exclusion of compressive extradural and detectable intramedullary processes by diagnostic imaging and laboratory testing. Degenerative myelopathy usually is an exclusionary diagnosis in practice. These facts are reflected in the limitations of our study. The positive findings from our study suggest that ambulation time can be increased in dogs with DM if the described physiotherapy protocol is applied.

Physiotherapy is an important part of rehabilitation in dogs affected with most neurologic diseases, and it improves the quality of life of the animal.[14,15] In chronic progressive neurodegenerative diseases such as DM, physiotherapy seemed to be an effective supportive therapy that increased ($P < .05$) survival time. Despite the inherent limitations of this study, including its retrospective design, our findings suggest that ambulation time was positively associated with the degree of physiotherapy. More-thorough evaluation, including physiotherapy performed by specifically trained veterinarians or physiotherapists and objective instruments for control of success of treated and untreated dogs, are necessary to further evaluate the efficacy of this treatment.

Footnotes

[a] Number Cruncher Statistical System (NCSS), 329 North 1000 East, Kaysville, UT

References

1. Averill DR Jr. Degenerative myelopathy in the aging German Shepherd Dog: Clinical and pathologic findings. J Am Vet Med Assoc 1973;162:1045–1051.

2. Griffiths IR, Duncan ID. Chronic degenerative radiculomyelopathy in the dog. J Small Anim Pract 1975;16:461–471.

3. Braund KG, Vandevelde M. German Shepherd Dog myelopathy—A morphologic and morphometric study. Am J Vet Res 1978;39:1309–1315.

4. Waxman FJ, Clemmons RM, Johnson G, et al. Progressive myelopathy in older German Shepherd Dogs: I. Depressed response to thymus-dependent mitogens. J Immunol 1980; 124(3):1209–1215.

5. Waxman FJ, Clemmons RM, Hinrichs DJ. Progressive myelopathy in older German Shepherd Dogs: II. Presence of circulating suppressor cells. J Immunol 1980;124(3):1216–1222.

6. Vandevelde M, Schawalder P, Ueltschi G. Degenerative Myelopathie beim Deutschen Schäfer. Schweiz Arch Tierheilk 1980;122:323–326.

7. Romatowsky J. Degenerative myelopathy in a German shepherd. Mod Vet Pract 1984;65:535–537.

8. Johnston PE, Barrie JA, McCulloch MC, et al. Central nervous system pathology in 25 dogs with chronic degenerative radiculomyelopathy. Vet Rec 2000;27:629–633.

9. Williams DA, Batt RM, Sharp NJH. Degenerative myelopathy in German shepherd dogs: An association with mucosal changes and bacterial overgrowth in the small intestine. Clin Sci 1984;66:25.

10. Williams DA, Prymak C, Baughan J. Tocopherol (vitamin E) status in canine degenerative myelopathy. American College of Veterinary Internal Medicine 3rd Annual Meeting San Diego, CA, July 1985.

11. Fechner H, Johnston PE, Sharp NJ, et al. Molecular genetic and expression analysis of α-tocopherol transfer protein mRNA in German Shepherd Dogs with degenerative myelopathy. Berl Münch Tierärztl Wschr 2003;116:31–36.

12. Clemmons RM. Degenerative myelopathy. In: Kirk RW, ed. Current Veterinary Therapy. Philadelphia, PA: WB Saunders; 1989:830.

13. Clemmons RM. Degenerative myelopathy. Vet Clin North Am Small Anim Pract 1992;22:965–971.

14. Jaggy A, Kathmann I. Rehabilitation. In: Alexander C-S, ed. Hrsg. Physikalische Therapie für Kleintiere. Berlin, Germany: Parey Buchverlag; 2001:182–206..

15. Kathmann I, Demierre S, Jaggy A. Rehabilitationsmassnahmen in der Kleintierneurologie. Schweiz Arch Tierhelk 2001; 143:495–502.

16. Hüsler J, Zimmermann H. Statistische Prinzipien für medizinische Projekte, 2nd ed. Bern, Switzerland; Huber; 2001.

17. Bichsel P, Vandevelde M, Lang J, et al. Degenerative myelopathy in a family of Siberian Husky dogs. J Am Vet Med Assoc 1983;183:998–1000.

18. Matthews NS, DeLahunta A. Degenerative myelopathy in an adult Miniature Poodle. J Am Vet Med Assoc 1985; 186:1213–1215.

19. Coates JR. Degenerative myelopathy of Pembroke Welsh Corgi Dogs. American College of Veterinary Internal Medicine 23rd Annual Meeting, Baltimore, MD, June 2005.

20. Salinas EM, Martinez NL. Description de un caso compatible con mielopatia degenerativa en un perro Mastin Ingles. Vet Mex 1993;24:159–162.

21. Levine JM, Hillmann RB, Erb HN, de Lahunta A. The influence of age on the patellar reflex response in the dog. J Vet Intern Med 2002;16:244–246.

22. Summers BA, Cummings JF, de Lahunta A. Veterinary Neuropathology. New York, NY: Mosby; 1995.

23. Clemmons RM, Wheeler S, LeCouteur RA. How do I treat a degenerative myelopathy. Prog Vet Neurol 1995;6:71–72.

24. Wiles CM, Newcombe RG, Fuller KJ, et al. Controlled randomised crossover trial of the effects of physiotherapy on mobility in chronic multiple sclerosis. J Neurol Neurosurg Psychiatry 2001;70(2):174–179.