

Temporospatial and kinetic gait variables of Doberman Pinschers with and without cervical spondylomyelopathy

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OBJECTIVE

To characterize and compare gait variables in Doberman Pinschers with and without cervical spondylomyelopathy (CSM).

ANIMALS

18 Doberman Pinschers (9 clinically normal dogs and 9 CSM-affected dogs).

PROCEDURES

A neurologic examination was performed on all dogs. The diagnosis of CSM was confirmed with MRI. Temporospatial and kinetic gait variables were measured by use of a pressure-sensitive walkway. Temporospatial variables evaluated included stance phase duration, swing phase duration, gait cycle duration, stride length, and gait velocity. Kinetic variables evaluated included peak vertical force and vertical impulse. Random-effects linear regression was used to determine the difference between CSM-affected and clinically normal dogs for each of the 7 variables.

RESULTS

Values for temporospatial variables were significantly smaller in the thoracic limbs of CSM-affected dogs, compared with values for the thoracic limbs of clinically normal dogs. For the kinetic variables, peak vertical force was significantly higher in the thoracic limbs than the pelvic limbs for all dogs. Vertical impulse values were higher in the thoracic limbs than the pelvic limbs. There were significant differences in mean vertical impulse between the thoracic and pelvic limbs for both groups.

CONCLUSIONS AND CLINICAL RELEVANCE

In this study, significant differences in temporospatial variables were identified between the thoracic limbs of clinically normal and CSM-affected dogs, with the values being smaller for the CSM-affected dogs than for the clinically normal dogs. A pressure-sensitive walkway may provide a valid, practical option for rapid, objective assessment of gait and response to treatment in dogs with CSM. (*Am J Vet Res* 2015;76:848–852)

Gait analysis plays an important role in the assessment of neurologic function in many diseases. In dogs with neurologic disease, gait is often assessed with subjective numeric rating scales.¹ Subjective evaluation of patients may cause bias because it is not always possible to adequately blind an evaluator.² Subjective rating scales are also insensitive at detecting subtle differences between groups.^{3–5} Developments in gait analysis instrumentation and software have allowed clinicians and researchers to accurately and efficiently assess the canine gait cycle.⁶ During a subjective evaluation, a clinician is only able to perceive a few kinematic variables at a time, but a modern kinematic or kinetic analysis system can capture, analyze, and store hundreds of observations per second.⁶

ABBREVIATIONS

CSM Cervical spondylomyelopathy
PVF Peak vertical force
VI Vertical impulse

Temporospatial variables, including stance phase duration, swing phase duration, gait cycle duration, stride length, gait velocity, and cadence, represent the basic pattern of critical events during a gait.⁷ Kinetic gait analysis provides an objective, noninvasive method for measuring ground reaction forces by use of measurement systems to evaluate kinetic variables.⁸ A pressure-sensitive walkway has been used to evaluate limb functions of dogs and cats and has revealed advantages for measuring kinematic and kinetic variables with the same equipment.^{9–11} Assessing neurologic status objectively by use of temporospatial and kinetic analysis can allow for unbiased assessment of treatment methods and outcome.

Cervical spondylomyelopathy is the most common disease of the cervical vertebral region of large- and giant-breed dogs, with Doberman Pinschers and Great Danes being overrepresented.^{12–14} Affected dogs have variable degrees of neurologic dysfunction, such as ataxia, tetraparesis or tetraplegia, and neck pain.^{15–17}

Diagnosis of CSM is based on patient history and results of neurologic examination and advanced diagnostic imaging or myelography.^{18–20} Both medical and surgical treatments can be used to treat CSM. However, surgical treatment offers a higher chance of improvement than does medical management.²¹ There is substantial controversy regarding surgical treatment of CSM because there are at least 27 surgical techniques proposed for treatment of the condition.¹² A major void in this field is the lack of methods to objectively assess outcome and compare results of treatments.

The objective of the study reported here was to characterize temporospatial and kinetic gait variables of clinically normal Doberman Pinschers during walking and to compare these quantitative variables with those of Doberman Pinschers with CSM. We hypothesized that there would be significant differences in temporospatial and kinetic variables between clinically normal and CSM-affected dogs.

Materials and Methods

Animals

Eighteen client-owned, skeletally mature Doberman Pinschers were enrolled in a prospective case-control study. The study was conducted in accordance with the guidelines and with the approval of the Clinical Research Advisory Committee and Institutional Animal Care and Use Committee of our institution. Recruitment of control and affected dogs was performed via the Clinical Trials Office of The Ohio State University College of Veterinary Medicine. Written informed consent was obtained from owners prior to enrollment of dogs in the study.

Recruitment was performed during a 13-month period. Dogs were considered clinically normal and eligible for study enrollment if they were ≥ 1 year old; no abnormalities were identified during physical, orthopedic, and neurologic examinations performed by 2 of the investigators (KDF and RCDC); and they had no previous orthopedic or neurologic disease.

Inclusion criteria for CSM-affected dogs included a history of pelvic limb ataxia, paraparesis, or tetraparesis with or without neck pain in a mature Doberman Pinscher in addition to neurologic examination findings consistent with cervical myelopathy. Physical and neurologic examinations, a CBC, serum biochemical analysis, radiography of the cervical vertebral region, and MRI examination of the cervical portion of the spinal cord were performed on all affected dogs. Neurologic status at the time of initial examination was graded on a scale from 1 to 5.²² Dogs classified as grade 1 had cervical hyperesthesia only; these dogs were excluded from the study. Dogs classified as grade 2 had mild ataxia or paresis of the pelvic limbs with mild involvement of the thoracic limbs. Thoracic limb involvement was defined as a short-stride or spastic gait with a long-stride appearance. Dogs classified as grade 3 had moderate ataxia or paresis of the pelvic limbs and mild involvement of the thoracic limbs as

described for grade 2. Dogs classified as grade 4 had marked ataxia or paresis of the pelvic limbs with mild involvement of the thoracic limbs. Dogs classified as grade 5 had nonambulatory tetraparesis; these dogs were also excluded from the study. The diagnosis of CSM was confirmed in all dogs by MRI in accordance with a published protocol²³ that supported evidence of spinal cord compression with or without spinal cord signal changes. Thoracic radiography was performed in all dogs > 7 years old ($n = 5$). Neurologic examinations of all dogs (clinically normal and CSM affected) were performed by 2 of the investigators (KDF and RCDC).

Study design

Data were collected by use of a high-resolution pressure-sensitive walkway^a (width, 0.50 m; length, 2.05 m) that contained 8,448 separate pressure-sensing elements. Sensors of the walkway were equilibrated and calibrated in accordance with the manufacturer's specifications prior to data collection for each dog. A video camera was positioned beside the walkway and used to record motion of the limbs.

Each patient was weighed on an electronic scale and then walked on a leash the length of the walkway for 5 to 10 minutes for acclimatization before data collection. Dog handlers were trained and experienced in research procedures. A trial was considered valid when a dog walked at a velocity within the range of 0.8 to 1.4 m/s, was not noticeably distracted, and remained within the boundaries of the pressure mat of the walkway with all 4 paws.

Five valid trials were obtained for each dog, and the data were analyzed with custom software^b that required manual identification of each limb and semi-manual measurement of temporospatial variables (stance phase duration, swing phase duration, stride length, and gait velocity). This analysis was repeated for every complete stride recorded on the pressure-sensitive walkway for all 4 limbs. Gait cycle duration was defined as the sum of the stance phase and the subsequent swing phase of the limb. Measurement of temporospatial variables was performed for limbs with complete gait cycles recorded on the walkway. Depending on the location of the first step on the walkway, 1 or 2 complete gait cycles were evaluated for each limb.

The kinetic variables PVF and VI were recorded for each paw placement on the pressure-sensitive walkway and were calculated automatically by the software. The PVF and VI were normalized on the basis of a dog's body weight and were reported as a percentage of body weight.

Statistical analysis

Random-effects linear regression was used to determine the difference between CSM-affected and clinically normal dogs for each of the variables. Each of the 7 regression models included terms for limb (thoracic vs pelvic) and side (right vs left). When de-

veloping each model, the interaction between condition (CSM-affected vs clinically normal) and limb was tested along with the interaction between condition and side. If either of these interactions was significant ($P < 0.05$), then the difference in the variable within a condition was estimated for each limb or for each side. Additionally, differences in the variables were estimated within limb or within side for each of the conditions. If the interaction terms were not significant, then they were removed from the model and the difference in the variables between conditions, between sides, and among limbs was estimated. Each of the 7 regression models was adjusted for dog age and body weight. Random effects were used because multiple observations were nested within a particular dog, which allowed for between- and within-patient variance when estimating the SE used to test model coefficients. All statistical analyses were performed with commercially available software,^c and significance was set at values of $P < 0.05$.

Results

A total of 18 dogs were enrolled in the study. The control group consisted of 9 clinically normal Doberman Pinschers (8 males and 1 female) with a mean \pm SD age of 4.3 ± 1.9 years (range, 1 to 7 years) and mean body weight of 38.3 ± 4.5 kg (range, 31.3 to 43.6 kg). The CSM-affected group consisted of 9 Doberman Pinschers (6 males and 3 females) with a mean \pm SD age of 7.7 ± 3.5 years (range, 3 to 12 years) and mean body weight of 37.4 ± 6.7 kg (range, 27.2 to 55.8 kg). Neurologic status of CSM-affected dogs was classified as grade 2 for 4 dogs, grade 3 for 2 dogs, and grade 4 for 3 dogs.

All CSM-affected dogs had spinal cord compression in the caudal aspect of the cervical portion of the vertebral column. The main compression was at C5 and C6 in 3 dogs and at C6 and C7 in 6 dogs. Data collection with the pressure-sensitive walkway was performed for all dogs without any complications.

Descriptive statistics of all temporospatial and kinetic variables were calculated (**Table 1**). On the basis of random-effects linear regression, mean values

of all temporospatial variables of gait, except gait velocity, of CSM-affected dogs were significantly smaller in the thoracic limbs than in the pelvic limbs (stance phase duration [$P = 0.014$], swing phase duration [$P < 0.001$], gait cycle duration [$P < 0.001$], and stride length [$P < 0.001$]). Mean values of all temporospatial variables of gait were significantly smaller in the thoracic limbs of CSM-affected dogs than in the thoracic limbs of clinically normal dogs (stance phase duration [$P = 0.021$], swing phase duration [$P = 0.025$], gait cycle duration [$P = 0.021$], stride length [$P = 0.002$], and gait velocity [$P = 0.021$]). Mean swing phase duration of clinically normal dogs was significantly ($P < 0.001$) smaller in the thoracic limbs than in the pelvic limbs. For all dogs, gait velocity ranged from 1.06 to 1.20 m/s (overall mean, 1.14 m/s), and gait velocity for all limbs did not differ significantly ($P = 0.553$) between groups. There were no significant differences in the temporospatial variables for all limbs between the left and right sides and for the pelvic limbs between clinically normal and CSM-affected dogs.

For kinetic variables, the mean PVF was significantly higher ($P < 0.001$) in the thoracic limbs than in the pelvic limbs of both groups. There were significant differences in mean VI between thoracic and pelvic limbs for both groups; mean VI was significantly ($P < 0.001$) higher in the thoracic limbs.

Discussion

Reference ranges for temporospatial and kinetic variables characteristic of gait have been established in some canine breeds to improve accuracy of gait analysis and provide an objective method for assessment of normal versus abnormal gaits.²⁴⁻²⁶ In the present study, the focus was on characterizing temporospatial and kinetic variables in CSM-affected Doberman Pinschers and determining whether they differed from equivalent measurements in clinically normal Doberman Pinschers. Analysis of data for this study supported the hypothesis that there were differences in temporospatial variables between clinically normal and CSM-affected dogs. For kinetic variables, there were no significant differences in PVF or VI between groups.

Table 1—Mean (95% confidence interval) values for temporospatial and kinetic variables obtained by use of a pressure-sensitive walkway (gait velocity range, 0.8 to 1.4 m/s) for 9 clinically normal and 9 CSM-affected Doberman Pinschers.

Variable	Clinically normal dogs		CSM-affected dogs	
	Thoracic limbs	Pelvic limbs	Thoracic limbs	Pelvic limbs
Stance phase duration (s)	0.527 (0.478–0.577)	0.510 (0.467–0.553)	0.439 (0.389–0.489)*	0.486 (0.438–0.535)†
Swing phase duration (s)	0.276 (0.252–0.300)	0.312 (0.290–0.333)‡	0.236 (0.214–0.258)*	0.311 (0.288–0.334)‡
Gait cycle duration (s)	0.785 (0.716–0.854)	0.812 (0.751–0.873)	0.665 (0.599–0.730)*	0.813 (0.745–0.880)‡
Stride length (m)	0.947 (0.871–1.022)	0.938 (0.877–1.000)	0.762 (0.679–0.846)*	0.858 (0.785–0.931)‡
Velocity (m/s)	1.206 (1.196–1.216)	1.155 (1.145–1.167)	1.145 (1.158–1.133)*	1.055 (1.053–1.057)‡
PVF (%BW)	66.0 (60.0–72.1)	44.1 (38.5–49.7)‡	66.3 (61.2–71.4)	49.2 (43.2–55.2)‡
VI (%BW X s)	23.4 (19.9–26.9)	13.7 (10.6–16.7)‡	19.8 (16.3–23.2)	14.4 (10.9–17.8)‡

*Value differs significantly ($P < 0.05$) from the value for thoracic limbs of the clinically normal dogs. †Within a group, value differs significantly ($\dagger P < 0.05$; $\ddagger P < 0.001$) from the value for the thoracic limbs.

%BW = Percentage of body weight.

In the present study, values for stance duration phase, swing duration phase, gait cycle duration, stride length, and gait velocity were smaller in the thoracic limbs of CSM-affected dogs. It appeared that the temporospatial variables could be used to discriminate between thoracic and pelvic limbs in a specific patient. In a previous digital motion capture study,²⁷ investigators found similar results for gait cycle duration in the thoracic limbs whereby values for CSM-affected dogs were smaller, compared with values for clinically normal dogs. Smaller values for temporospatial variables in CSM-affected dogs of the study reported here are similar to those reported in another study² in which dogs with T3-L3 myelopathy were found to have reductions in stance phase duration, gait cycle duration, and stride length. Interestingly, in dogs affected with T3-L3 myelopathy, swing phase duration was increased in the pelvic limbs.² In the present study, dogs with CSM did not have significant differences in the swing phase duration of their pelvic limbs, compared with values for the clinically normal dogs.

It is generally assumed that dogs carry approximately 60% of their body weight on the thoracic limbs and 40% of their body weight on the pelvic limbs when walking at a velocity of 0.7 to 1.0 m/s, but this has not been confirmed for specific dog breeds or types.^{8,28,29} In addition, it has been observed that ataxic dogs have a tendency to shift even more of their weight onto the thoracic limbs as a result of pelvic limb ataxia.² In the study reported here, mean PVF was 65.9% of body weight on the thoracic limbs and 46.3% of body weight on the pelvic limbs, without significant differences between groups. These findings indicated that dogs with CSM did not have the same tendency to shift more weight onto the thoracic limbs, which is in contrast to the results for dogs affected by T3-L3 myelopathy.² It is certainly conceivable that the variety of body conformations in domestic dog breeds could affect the location of the center of gravity and thus the thoracic limb versus pelvic limb impulse distribution, which in turn would naturally influence forces and impulses for individual limbs.³⁰ Therefore, this could explain the significant differences in mean VI between the thoracic and pelvic limbs of both groups. In the clinically normal dogs, mean VI was 13.7% of body weight and 23.4% of body weight for the pelvic and thoracic limbs, respectively, whereas in the CSM-affected dogs, it was 14.4% of body weight and 19.8% of body weight for the pelvic and thoracic limbs, respectively. This also may be associated with the weakness (paresis) evident in CSM-affected dogs. Moreover, VI is significantly affected by the duration of a stance phase.²⁹ However, the smaller stance phase duration found in the thoracic limbs of CSM-affected dogs in the present study did not interfere significantly with the VI of these dogs, when compared with results for clinically normal dogs. There is a relationship between velocity and PVF determined with a force plate or pressure-sensitive walkway,³¹ and it is therefore important to control the velocity when conducting these exami-

nations. Velocity and acceleration can affect kinetic variables in dogs; therefore, velocity and acceleration variables have been maintained within tight limits in most studies.³¹⁻³⁴ Selection of a velocity of 0.8 to 1.4 m/s for the study reported here was based on recommendations from other studies.³¹⁻³⁴ Determination of velocity by use of the pressure-sensitive walkway did not take into account the fact that appendicular limb segment velocity (ie, limb velocity) may differ among dogs because of morphological differences. However, we only evaluated Doberman Pinschers (a fairly homogeneous morphological population), and we determined that gait velocity for all limbs was not significantly different between groups. Additionally, even if differences in gait velocity had been found for the thoracic limbs, it is unlikely that they would have affected results for the kinetic variables.

The primary limitation of the study reported here was the relatively small sample size, which might have led to a type II error and not allowed us to detect differences in PVF in the pelvic limbs and VI in the thoracic limbs between groups. However, we focused on a single breed with clinically normal and CSM-affected dogs. This allowed us to provide ranges for the temporospatial variables and PVF that will facilitate further studies in Doberman Pinschers. This is particularly relevant because reference ranges may be affected by the intrinsic variability of gait and conformation of an individual dog and also by breed differences.³⁰

In a previous study,¹⁰ it was found that the data obtained with a pressure-sensitive walkway for PVF in the thoracic limbs were significantly different from the data obtained with a force plate. Several possibilities exist to explain the differences in data between the pressure-sensitive walkway and force plate; one of them is the form of calibration of the equipment. However, another force plate study³⁵ that involved use of a population similar to the one used in the present study also did not detect differences in mean PVF between limbs of clinically normal and CSM-affected dogs. When VI data for the present study were compared with data from the aforementioned force plate study,³⁵ differences in the results were found. However, a pressure-sensitive walkway has an important advantage over a force plate, which is the ability to obtain full-stride data with a reliable measure of step-to-step speed changes. Force plates are excellent for quantifying limb use in dogs with lameness, but they can be problematic in dogs with moderate to severe ataxia that typically overload or underload a particular thoracic or pelvic limb in a random manner. One approach to avoiding this problem would be to use 2 or more linked force plates to ensure direct measurement of PVF and VI for all 4 limbs on each trial. In the present study, we elected to use a pressure-sensitive walkway to achieve the same goal.

The comprehensive data output from the pressure-sensitive walkway supported its utility as an objective measure of gait analysis in clinical cases of CSM. All temporospatial variables in the present study

differed between clinically normal and CSM-affected dogs. By establishing reference values for output of a pressure-sensitive walkway for clinically normal Doberman Pinschers, and by detecting significant differences between clinically normal and CSM-affected dogs, we anticipate that future studies on CSM will be able to incorporate quantitative analysis of data obtained with a pressure-sensitive walkway as a means of tracking response to treatment and discriminating among results for the various medical and surgical treatment options available for CSM-affected dogs.

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Footnotes

- a. HR Mat high-resolution floor mat force measurement system, Tekscan, South Boston, Mass.
- b. Walkway gait analysis system 6.31, Tekscan, South Boston, Mass.
- c. Stata, version 12.1, Stata Corp, College Station, Tex.

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