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Is a Pressure Walkway System Able to Highlight a Lameness in Dog?

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Abstract: The aim of this study was to evaluate spatio-temporal and pressure parameters of lame large-breed dogs at a walk compared to sound dogs and to assess left/right limb symmetry and fore/hind limb ratio of those parameters. A 4.3 m electronic walkway system was used to record and calculate spatio-temporal and pressure parameters in 8 healthy and 4 lame adult large-breed dogs at walk. At walk, gait was found symmetrical for all sound dogs and no significant difference was detected for the left and right symmetry for any parameters. The values of fore/hind limb ratio showed a more significant distribution on the forelimb rather than the hind limb for the stance time, relative stance time; for the peak vertical pressure and number of activated sensors. This system was able to determine and quantify the asymmetry and abnormal gait on lame dogs. Modification of the fore/hind limb ratio has been observed with abnormal postures due to orthopedic lesions. The results from this study corresponded well with the clinical signs and radiological examination. The evaluation of symmetry was quicker and easier way to perform than comparing the absolute values of each parameter. The left/right symmetry and fore/hind limb ratio may be a good way to qualify and quantify a gait for lame dogs in a clinical setting. Based on these results, the pressure walk way proved to be a quick and useful tool for gait analysis and for long term lameness follow-up.

Key words: Pressure walkway, sound dogs, lame dogs, gaitrite, gait analysis, fore/hind limb ratio, left/right symmetry

INTRODUCTION

Canine gait analysis may be realized by many different techniques: kinematic and kinetic analysis. Force platforms have frequently been used to evaluate the kinetic parameters of the limbs of dogs, particularly the peak vertical force and vertical impulse (Bennett *et al*., 1996; Bertram *et al*., 2000; Besancon *et al*., 2003; Bockstahler *et al*., 2007; Brebner *et al*., 2006; Budsberg *et al*., 1987, 1993, 1996, 1999; DeCamp *et al*., 1996; Fanchon *et al*., 2006; Fanchon and Grandjean, 2008; Gilette and Angle, 2008; Jevens *et al*., 1993; Kennedy *et al*., 2003; Lister *et al*., 2009; Madore *et al*., 2007; McLaughlin and Roush, 1994, 1995; McLaughlin, 2001; Renberg *et al*., 1999; Riggs *et al*., 1993; Roush and McLaughlin, 1994; Voss *et al*., 2007, 2008; Waxman *et al*., 2008). Force platform has been used to evaluate gait analysis for dogs at a walk (Besancon *et al*., 2003, 2004; Bockstahler *et al*., 2007; Budsberg *et al*., 1987; Roush and McLaughlin, 1994), trot (Bertram *et al*., 2000; Brebner *et al*., 2006; Budsberg *et al*., 1993; Fanchon *et al*., 2006; Fanchon and Grandjean, 2007, 2008; Jevens *et al*., 1993; Kennedy *et al*., 2003; Madore *et al*., 2007; McLaughlin and Roush, 1994; Renberg *et al*., 1999; Riggs *et al*., 1993) and while jumping (Yanoff *et al*., 1992). They have been used not only in the study of locomotion of healthy dog (Besancon *et al*., 2003; Bockstahler *et al*., 2007; Budsberg *et al*., 1987, 1993; Bertram *et al*., 2000; Fanchon *et al*., 2008; Jevens *et al*., 1993; Kennedy *et al*., 2003; McLaughlin and Roush, 1994, 1995; Renberg *et al*., 1999; Riggs *et al*., 1993; Roush and McLaughlin, 1994; Voss *et al*., 2007; Waxman *et al*., 2008), but also extensively to compare forces, before and after surgery (Budsberg *et al*., 1988; Jevens *et al*., 1996); evaluate dogs with hip dysplasia (Bennett *et al*., 1996; Kennedy *et al*., 2003; Lister *et al*., 2009; Madore *et al*., 2007); rupture cranial cruciate ligament (DeCamp *et al*., 1996; Voss *et al*., 2008); synovitis (Rumph *et al*., 1993); diagnosis lameness (Fanchon and Grandjean, 2007; Voss *et al*., 2007); experimentally induced lameness (Waxman *et al*., 2008) and to determine the efficiency of medical or surgical treatments of osteoarthritis (Budsberg *et al*., 1996, 1999).

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Nevertheless, the force platform presents several limits. The system is hardly portable and requires to be integrated in the floor in a specific room, treatment of data could be difficult and time consuming. Moreover, data cannot be collected from all four limbs during one cycle using a single force platform (Brebner *et al*., 2006). Consecutive strides cannot be assessed without an associated treadmill (Bockstahler *et al*., 2007; Fanchon *et al*., 2006; Fanchon and Grandjean, 2008). Several trials were necessary to obtain correct placement of the foot on the plate.

Because of those limits, other systems have been developed recently such as the pressure walkway system also called pressure sensors system. Most were designed to measure spatio-temporal gait analysis and built around pressure sensors included in a walkway. Data collection and analysis were performed by specific software. Pressure walkway was used recently in some research for humans (Cutlip *et al*., 2000; Bilney *et al*., 2003; McDonough *et al*., 2001; Menz *et al*., 2004; Titianova *et al*., 2004; Webster *et al*., 2004; Youdas *et al*., 2006) but still very little in animals such as dogs (Besancon *et al*., 2003, 2004; Lascelles *et al*., 2006; Kim *et al*., 2006); cats (Lascelles *et al*., 2007; Romans *et al*., 2004) and sheep (Kim and Breur, 2008).

Recently, a human gait analysis tools have introduced GAITRite® system, a pressure mat, which measures spatio-temporal parameter, peak vertical pressure and velocity of the human gait.

For dogs, this pressure walkway, combined with an original quadruped software was able to calculate many spatio-temporal parameters for each limb at the same time and in the same experimental conditions at walk.

This portable system allowed us recording data of the consecutive four feet in a single pass so that an adequate amount of data can be collected by fewer passes over the walkway to compare with the force plate, which needs many passes for only one foot (Besancon *et al*., 2003).

Studies recently assessed the concurrent validity of the GAITRite® system in humans with video-based analysis system (Cutlip *et al*., 2000); paper-and-pencil and video-based methods (McDonough *et al*., 2001); a foot switch system (Bilney *et al*., 2003); a 3-dimensional motion analysis system: Vicon-512 (Webster *et al*., 2004) and stopwatch-footfall count method (Youdas *et al*., 2006), all of these reports demonstrated that the results of validity and reliability of this system for gait analysis were excellent. We have observed in a personal preliminary unpublished study that dog results with this system seemed to have the same validity and reliability (Viguier *et al*., 2006).

However, evaluation of the parameters of gait analysis in normal and abnormal clinical dogs has never been assessed with this system.

The purpose of this prospective study was to evaluate the spatio-temporal and the pressure parameters in healthy small-breed dogs and to compare with lame dogs by using a 4.3 m pressure sensors walkway GAITRite®.

MATERIALS AND METHODS

Eight sound adult large-breed dogs (2 males and 6 females) from 1-6 years old with the mean age 2.8±1.6 (SD) years and the body weight from 19-36 kg with the mean 28.2±5.2 (SD) kg were recruited from the staff of the National Veterinary School of Lyon and tested with a GAITRite® system. All dogs underwent an orthopedic examination showing neither visible lameness nor appendicular and vertebral joint or muscle pain. No history of orthopedic disease was recorded before for any dog.

Four adult large-breed dogs with clinical and radiographic evidence of lameness from 1-4 years old and the body weight from 22-58 kg belonging to clients of the veterinary hospital of the National Veterinary School of Lyon, included in this study:

- A fragmentation of the sesamoid bones of the II and IV left metacarpus was diagnosed for the first dog (Labrador female, age of 1 year and body weight of 26 kg)
- An incongruent articulation and low grade osteoarthritis of the right elbow was diagnosed for the second dog (Boxer male, age of 3 years and body weight of 26.6 kg)
- The cranial cruciate ligament rupture of the left knee was diagnosed for the third dog (Setter male, age of 4 years and body weight of 22 kg)
- A bilateral hip dysplasia and more important on the right hip with osteoarthritis signs was diagnosed for the fourth dog (Golden retriever female, age of 4 years and body weight of 58 kg)

The GAITRite® system (CIR systems, Inc.) includes a portable walkway 4.3 m long, which has seven sensor pads with an active area of 61 cm wide and 427 cm long. The active area contains 16128 sensors arranged in a grid pattern, which measures spatiotemporal aspects of gait. The spatial resolution of the device is 1.27 cm and the sampling frequency is 80 Hz. The data was collected by the activated sensors and transferred to a portable computer through a serial port where it was calculated by specialized quadruped-adapted software (GAITFour) and this data was then exported for further processing and analysis.

Before collecting data, 6-8 practice trials were performed across the walkway to familiarize the dogs with their environment and the protocol. For each dog, all trials were completed in one session and on 1 day. The dogs walked with their owner across the walkway utilizing a loose leash. The dogs walked at their preferred and constant velocity, while an observer evaluated and confirmed the validity of each trial. A trial was considered valid when all of four paws were in contact with the surface of the walkway for each walk cycle; the dogs maintained a steady-state, straight line gait pattern without pulling on the leash or turning the head and there were at least three consecutive regular strides to analyze. Only dogs at walk were included. Visual analysis and gait computerized pattern evaluation allowed us to reject other gait patterns like trot or run. Five valid trials were recorded for each dog.

This system collected spatio-temporal and pressure data, time and location of footprints, pressure and number of sensors activated during the stance. Followed parameters have been chosen regarding bibliography of previous kinetic and kinematic studies of the walk in dogs and regarding previous pressure walkway system studies done in humans (Cutlip *et al*., 2000; Bilney *et al*., 2003; McDonough *et al*., 2001; Menz *et al*., 2004; Titianova *et al*., 2004; Webster *et al*., 2004; Youdas *et al*., 2006). A personal and original software was developed with Microsoft Excel® to calculate spatio-temporal parameters.

The extrapolated spatial parameter was the stride length (cm). The extrapolated temporal parameters included: stance time (sec); relative stance time or stance time percent (stance time/stride time); stride time (sec) and the walking velocity (m sec^{-1}).

The extrapolated kinetic parameter was the peak vertical pressure (maximal pressure during stance). Number of activated sensor allowed assessing the footprint area with a low spatial resolution.

In addition to the data/parameters collected directly by GAITRite®, we calculated for all parameters the ratio of the fore/hind limbs and the symmetry of left/right limbs; left/right forelimbs and left/right hind limbs.

We consider a gait symmetric, when values of contralateral limbs are quite similar, so the symmetries of left/right limbs; left/right forelimbs and left/right hind limbs are closed to one (with a 4% error interval).

Statistical test were used for the sound dogs to evaluate the symmetry of left and right; fore and hind. Normalized data were tested for normal distribution using the Shapiro-Wilks test.

The statistical student's t-test were used for the parametric data or Mann-Whixtney Wilcoxon tests were used for the non-parametric data in order to make a comparison in gait parameters between the left and right forelimbs; the left and right hind limbs and forelimb and hind limb. Difference was considered significant if $p<0.05$.

RESULTS AND DISCUSSION

Sound dogs: The mean velocity of the sound large breed dogs was 1.09 (SD 0.33) m sec^{-1}. This value was slightly higher than the results of former studies in healthy large-breed dogs for walking velocities that were around 1 m sec^{-1} (Besancon *et al*., 2003, 2004; Hottinger *et al*., 1996; Roush and McLaughlin, 1994).

The values of stand time and relative stand time were significantly different and upper for the forelimbs than the hind limbs (0.40 versus 0.37 and 58.1 versus 53.5, respectively). The values stride time of each leg presented no significant difference and were always close to 0.67 sec. The values stride lengths of each leg presented no significant difference and were always close to 82.5 cm.

The stance time of forelimbs was 0.40 (SD 0.04) and for the hind limbs was 0.37 (SD 0.04).

The results of stance time were slightly less than the report of Roush and McLaughlin (1994) in their report for the healthy large breed dogs (body weight range from 28.76-36.25 kg) at the walking velocity lower than us (0.92-1.03 m sec^{-1}), the stance time for the forelimb and hind limb were from 0.43-0.48 and from 0.40-0.45 sec, respectively. In previous studies, stance time in the forelimbs and hind limbs had been shown to have a negative linear correlation with velocity (McLaughlin and Roush, 1994, 1995; Renberg *et al*., 1999; Roush and McLaughlin, 1994).

The peak vertical pressure and the number of activated sensors were significantly different and upper for the fore limbs than the hind limbs (51.0 versus 34.8 and 16.5 versus 12.8, respectively).

We did not detect significant differences between the left and right forelimbs or left and right hind limbs for any parameters (Table 1).

The values of fore/hind limb ratio in the sound dogs showed a more significant distribution on the fore limb rather than the hind limb for the stance time and relative stance time and the peak vertical pressure (Fig. 1). It corresponded well with the previous studies in healthy dogs at walk published by Besancon *et al.* (2003, 2004), Bockstahler *et al.* (2007) and Roush and McLaughlin (1994).

The ratio of fore/hind limb of the stance time was 1.10 (SD 0.10). This result was slightly higher than ratio calculated from earlier studies of Bockstahler *et al.* (2007)

Table 1: The values for data collected in sound large-breed adult dogs at walk (Mean±SD)

Limb	Stance time (sec)	Relative stance time (cycle (%))	Stride time (sec)	Stride length (cm)	Peak vertical pressure	No. activated sensors
Left forelimb	0.40±0.11	58.1±6.78	0.68±0.07	82.6±6.36	50.8±8.58	16.6±2.09
Right forelimb	0.39±0.10	58.1±5.73	0.67±0.06	82.5±6.63	51.1±7.73	16.3±2.06
Left hind limb	0.37±0.11	53.5±8.11	0.67±0.06	82.4±6.64	34.7±5.82	12.7±2.06
Right hind limb	0.37±0.11	53.5±8.83	0.67±0.06	82.5±6.25	34.8±4.84	12.8±1.39
Forelimbs	0.40±0.11*	58.1±6.21*	0.67±0.06	82.5±6.44	51.0±8.08*	16.5±2.06*
Hind limbs	0.37±0.11	53.5±8.38	0.67±0.06	82.5±6.39	34.8±5.29	12.8±1.37

No significant differences were detected between left and right forelimb; Left and right hind; Indicates a significant difference between forelimbs and hind limbs ($p<0.05$)

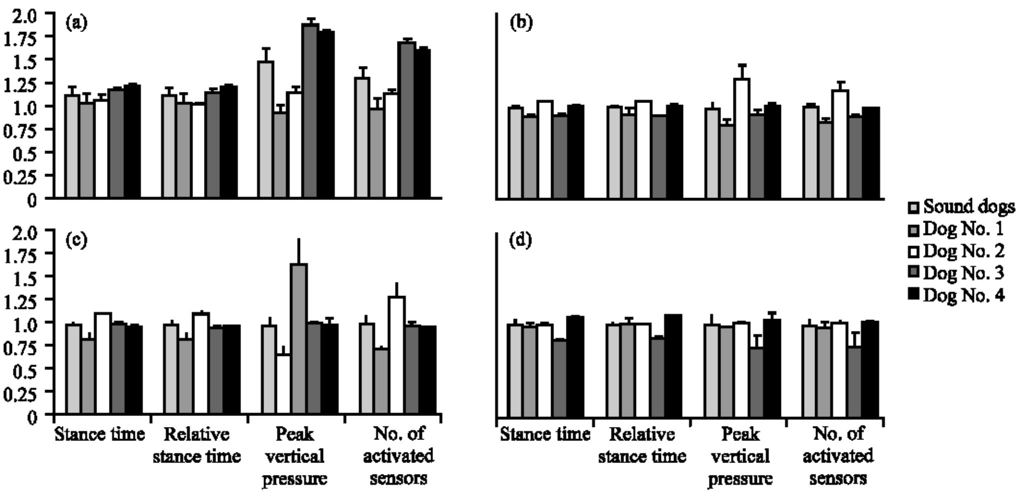

Fig. 1: The symmetry of a) fore/hind limb ratio; b) left/right limbs; c) left/right forelimb and d) left/right hind limb of sound and lame dogs at walk

and Hottinger *et al.* (1996): 1.04 and 1.03, respectively. The fore/hind limb ratio for stride time and stride length were about the value 1.

The fore/hind limb ratio of peak vertical pressure was 1.47 (SD 0.14). The values in large dogs were similar with the recent reports in healthy large-breed dogs were 1.42 (Besancon *et al.*, 2004) or 1.46 for system platform and 1.38 for system pressure mat (Besancon *et al.*, 2003). But this value in the study was lower than the result 1.61 of Bockstahler *et al.* (2007) and higher than the result 1.38 of Budsberg *et al.* (1987).

The values of the symmetry of left/right limbs; left/right forelimbs and left/right hind limbs for all of spatio-temporal parameters; peak vertical pressure and number of activated sensors in all of dogs were 1 or close to 1.

To the researchers knowledge, it has never been demonstrated before the ratio of fore/hind limb in the sound dogs. Fore/hind limb ratio could be interesting to assess front or hind limb lameness but needs to be compared with the same conformation healthy dogs. Actually, we have found no information concerning the walking-gait of healthy dogs with this type of pressure walkway system to compare with this study's results.

Symmetry between left and right legs was present in all of dogs for all parameters and no significant variation in symmetry was found with size and weight variation for almost all parameters. We can assume, with the limitation of this gait analysis system, that the walk of the sound dogs is a symmetric gait with symmetric values for the left and right forelimbs and for the left and right hind limbs.

Lame dogs: Because of the different body weight and velocity we used the values of symmetry left/right and fore/hind limb ratio to compare between every lame dog and eight sound large-breed dogs.

The values symmetry and ratio of all parameter of lame dogs were difference with those of sound dogs, except the stride time and stride length (1 or close to 1).

Dog No. 1: The orthopedic examination showed a lameness of the left forelimb at walk, dog was painful during palpation on the finger IV of left metacarpus. The results of radiological examination showed a fragmentation of the sesamoid bones of left metacarpus II and IV.

The test with the system pressure walkway showed: the mean velocity was 1.00 m sec^{-1} (SD 0.03). The fore/hind limb ratio for the peak vertical pressure and the number of activated sensor were 0.91 and 0.96, respectively. These values were less than those of the sound dogs (1.47 and 1.29). The fore/hind limb for stance time and relative stance time were lower than sound dogs (1.02 versus 1.10 and 1.03 versus 1.10, respectively).

That means dog supported fewer and shorter on the forelimbs than the hind limbs. The symmetry left/right limbs of all parameter were from 0.82-0.93; dog supported more on the right than the left side.

The symmetry left/right forelimb of stance time, relative stance time, peak vertical pressure and number of activated sensors were significantly <1. Dog supported longer and stronger on the right than the left forelimb (Fig. 1). The symmetry left/right hind limb for all parameters were always close to 1 same as the sound dogs. This means that hind limbs have the same kinematics and kinetics.

The data obtained from this pressure walkway can show us clearly the left forelimb lameness. This result corresponded well with the results of orthopedic and radiological examination.

Dog No. 2: The orthopedic examination showed a lameness of the right forelimb at walk, dog was painful at mobilization of elbow joint; radiological examination showed an incongruent articulation and low grade osteoarthritis of the right elbow. A right elbow dysplasia was diagnosed.

The velocity was lower than the sound dogs, 0.83 m sec^{-1} (SD 0.10) versus 1.09 m sec^{-1}. The fore/hind limb ratio for the peak vertical pressure and number of activated sensors were lower than sound dogs (1.13, 1.47 and 1.13 versus 1.29, respectively). That means dog No. 2 supports fewer on forelimbs than hind limbs.

The symmetry left/right for all parameters ranged from 1.08-1.34, except the stride time and the stride length; that means dog supported more on the left than the right side. The symmetry left/right forelimb for all parameters (except stride time and stride length) were superior than 1 (1.14-1.72) that means dog supported longer and stronger on the left than the right forelimb (Fig. 1).

The symmetry left/right hind limb for all parameters were always close to 1 same to the sound dogs. As for the first dogs, this means hind limbs have the same kinematics and kinetics.

The data obtained from this pressure walkway can show us clearly the right forelimb lameness. This result corresponded well with the results of orthopedic and radiological examination.

Dog No. 3: The orthopedic examination showed an amyotrophy and a lameness of the left hind limb at walk, dog was painful at extension of the left stifle. The cranial thrust was positive. Radiological examination showed signs of cranial cruciate ligament rupture.

The velocity was slightly higher than the sound dogs, 1.20 m sec^{-1} (SD 0.10) versus 1.09 m sec^{-1}. The fore/hind limb ratio for the peak vertical pressure and number of activated sensors were higher than sound dogs (1.88, 1.47 and 1.67 versus 1.29, respectively). That means dog supports fewer on hind limbs than forelimbs.

The symmetry left/right for all parameter ranged from 0.91-0.94, except the stride time and the stride length that means dog supported more on the right than the left side.

The symmetry left/right forelimb for all parameters were always close to 1 same to the sound dogs. This means that forelimbs have the same kinematics and kinetics.

The symmetry left/right hind limb for all parameters (except stride time and stride length) were <1 (0.75-0.86); that means dog supported longer and stronger on the right than the left hind limb (Fig. 1).

The data obtained from this pressure walkway can show us clearly the left hind limb lameness. This result was corresponded well with the results of orthopedic and radiological examination.

Dog No. 4: The orthopedic examination showed a hind limbs lameness, pain was present on the both hip at palpation and mobilization. Radiological examination showed a bilateral hip dysplasia and more important on the right hip with osteoarthritis signs.

The velocity was lower than the sound dogs, 0.68 m sec^{-1} (SD 0.10) versus 1.09 m sec^{-1}. The fore/hind limb ratio for the peak vertical pressure and number of activated sensors were very higher than the sound dogs (1.80, 1.47 and 1.60 versus 1.29, respectively). That means dog supports fewer on hind limbs than forelimbs.

The symmetry left/right for all parameters were closed to 1, these values was not interested. The symmetry left/right forelimb for all parameters were always close to 1 (0.97-1.02) similar with the sound dogs. This means that forelimbs have the same kinematics and kinetics.

The symmetry left/right hind limb for all parameters (except stride time and stride length) were >1 (1.04-1.10); that means dog supported longer and stronger on the left than the right hind limb (Fig. 1). The data obtained from this pressure walkway can show us clearly the right hind limb lameness.

The results of four lame dogs were corresponded well with the results of orthopedic and radiological examination. This system pressure walkway could be used to find and quantify the asymmetry and abnormal gait on lame dogs. When the velocity and body weight were not the same, the values symmetry left/right and the fore/hind limb ration were useful to compare between the sound and lame dogs.

CONCLUSION

The GAITRite® system was proved to provide useful data: spatio-temporal parameters, maximal pressure and number of activated sensors of the dog at walk and allowed quick analysis.

On the basis of the data obtained in this study and compared with the earlier studies, it could be concluded that the results were similar to those found in literature for sound large breed dogs which used other gait analysis devices. So, we can accept this data as normal values of reference.

As already published, every orthopedic pathology induces lameness and a modification of the symmetric pattern of the gait. This system was proved the capacity to qualify and quantify the lameness. According to this study, the use of the left/right limb symmetry and fore/hind limb ratio could help the clinician to determine the pathologic limb and quantify the lameness. These measurements may help clinician to verify diagnosis and to realize reliable and accurate follow-up after treatment.

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