Gait analysis for sound dogs at a walk by using a pressure walkway

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Abstract— **The purpose of this study was to evaluate spatio-temporal and pressure parameters in two different sized dogs: large-breed (Retriever) and small-breed dogs (Beagle), by using a pressure sensors walkway. 55 healthy adult dogs from 1 to 4.5 years old: 28 Retriever (mean weight: 29.7 kg) and 27 Beagle (mean weight: 10.8 kg) were tested by GAITRite® system. It is a portable pressure walkway of 4.3 meters long and 16128 sensors, which measures spatio-temporal and pressure parameters. Data collected included: stance time; relative stance time (stance time/stride time), stride time; stride length; peak vertical pressure, number of activated sensors by each paw; cadence and walking velocity. Symmetry left/right and ratio fore/hind limbs were also calculated. No significant difference for mean of velocity for Retriever (1.09 m/s) and Beagle dogs (1.14 m/s), but a significant different for the cadence between large (1.6) and small dogs (2.09) stride/s. No significant difference between the left and right forelimbs or left and right hind limbs for any parameters in either group. But the differences were significantly for all parameters between two groups.**

The values of fore/hind limb ratio in both groups showed a more significant distribution on the forelimb than the hind limb for stance time; relative stance time; the peak vertical pressure and were significantly difference between large and small dogs (1.07 versus 1.12; 1.08 versus 1.15 and 1.60 versus 1.45, respectively). The GAITRite® analysis system enables measurement of the spatial-temporal parameters of the dog at walk. The study of symmetry and ratio allow an easier and quicker gait analysis. The size of dogs influenced the fore/hind ratio and significant difference; however the left and right symmetry did not seem to be modified. Pressure, relative stance time and number of activated sensors were more important in the forelimb than for the hind limb.

Keywords— **Pressure walkway, gait analysis, healthy dog, GAITRite® system, ratio**

I. INTRODUCTION

Scientific gait analysis of canines has evolved over the past 25 years, most dramatically over the past decade thanks to improvements in computer technology. Gait analysis may be realized by many different techniques: kinematic and kinetic analysis.

Kinetic analysis is an analysis of the forces acting on a system motion and has been described by many authors [1-8] using several devices such as force platforms, treadmill associated with force platforms, pressure mats….

Force platforms were mainly used to obtain sensitive and reliable data: the ground reaction forces (peak vertical and horizontal forces, vertical impulse, acceleration, symmetry, etc). Nevertheless the force platform presents several limits. The system is complex, hardly portable and requires a specific environment and conditions of use. Moreover, data cannot be collected from all four limbs during one cycle using a single force platform [7]. Consecutive strides cannot be assessed without an associated treadmill [8]. 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 was performed by specific software. Pressure walkway was used recently in some research for humans [9-14] but still very little in animals such as dogs [6, 15-17], cats [18] and sheep [19].

Locomotion in healthy dogs has been characterized in several experimental force platform studies [1-8], but rarely, to the author's knowledge, with a pressure sensor system [6, 15, 16]. However the influence of the size has never been assessed with that system.

The purpose of this prospective study was to evaluate spatio-temporal and pressure parameters in two different sized dogs: healthy large-breed and small-breed dogs, by using a 4.3 meter pressure sensors walkway.

II. MATERIALS AND METHODS

Fifty-five adult dogs were included in this study: 28 healthy Retrievers (average aged: 2.3 years, SD 1 and average weight: 29.7 kg, SD 3.9) owned by the National association for training dogs for the disabled and 27 healthy adult Beagles (average aged: 1.7 years, SD 1.1 and average weight: 10.8 kg, SD 0.8) were recruited from Institute Claude Bourgelat of the National Veterinary School of Lyon. 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.

The GAITRite® system (CIR Systems, Inc.) includes a portable walkway 4.3 meters long, which has seven sensor pads with an active area of 61 cm wide and 427 cm long. The active area contains 16,128 sensors arranged in a grid pattern which measure 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, six to eight practice trials were performed across the walkway to familiarize the dogs with their environment and the protocol. The dogs walked with an experienced handler (the same handler for each dog for all trials) 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 their heads; and there were at least three consecutive regular strides to analyze. Five valid trials were recorded for each dog.

This system collected spatio-temporal (stride length, stance time, relative stance time or stance time %, stride time, cadence and walking velocity) and pressure data: peak vertical pressure and number of sensors activated during the stance.

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

The statistical paired t-test was used in order to make a comparison in gait parameters between left and right forelimbs, and the left and right hind limbs. The Mann-Whistney Wilcoxon tests were performed to determine if difference in measurement of each gait parameter between two groups was significant. Difference was considered significant if p was under 0.05.

III. RESULTS

The velocity of Retrievers was 1.09 (SD 0.18) m/s versus 1.14 (SD 0.36) m/s for Beagles group.

A significant difference was observed for the value of cadence between breeds: Retrievers = 1.6 (SD 0.2) strides/s; Beagles = 2.09 (SD 0.22) strides/s.

We did not detect significant difference between the left and right forelimbs or left and right hind limbs for any parameters in either group.

There were significant differences for all spatio-temporal parameters; peak pressure and number of activated sensors between Retrievers and Beagles group. These data from Beagle group were consistently lower than those of group of Retriever.

The symmetry of left/right limbs; left/right forelimbs and left/right hind limbs for all of spatio-temporal parameters; peak pressure and number of activated sensors in either group were not significantly different by 1 and there were no significant differences between two groups (table 1).

Table 1. The symmetry values for variables collected in healthy Retrievers and Beagles dogs at walk (Mean±SD)

Parameters	Symmetry	Retrievers	Beagles
Stance time (s)	Symmetry L/R	1.00±0.03	1.00±0.10
	Symmetry LF/RF	1.00±0.04	0.99±0.11
	Symmetry LH/RH	1.00±0.07	1.01±0.19
Relative stance time (% of cycle)	Symmetry L/R	1.00±0.03	0.99±0.12
	Symmetry LF/RF	1.00±0.04	0.99±0.12
	Symmetry LH/RH	1.01±0.05	1.01±0.26
Stride time (s)	Symmetry L/R	1.00±0.01	1.00±0.02
	Symmetry LF/RF	1.00±0.02	0.99±0.03
	Symmetry LH/RH	1.00±0.02	1.01±0.04
Stride length (cm)	Symmetry L/R	1.00±0.01	1.00±0.01
	Symmetry LF/RF	1.00±0.01	1.00±0.02
	Symmetry LH/RH	1.00±0.01	0.99±0.02
Peak pressure	Symmetry L/R	0.99±0.11	1.02±0.15
	Symmetry LF/RF	1.00±0.13	1.03±0.19
	Symmetry LH/RH	0.99±0.14	1.04±0.25
Number of activated sensors	Symmetry L/R	1.00±0.09	1.01±0.12
	Symmetry LF/RF	1.01±0.11	1.01±0.18
	Symmetry LH/RH	1.00±0.13	1.04±0.20

L/R = left fore and hind limbs/right fore and hind limbs; LF = left forelimb; RF = right forelimb; LH = left hind limb; RH = right hind limb

No significant differences were detected between Beagles and Retrievers dogs.

The fore/hind limb ratio of stance time was 1.07 (SD 0.07) for large breed dogs and 1.12 (SD 0.17) for Beagles, this ratio for relative stance time was 1.08 (SD 0.05) for Retrievers and 1.15 (SD 0.14) for small-breed. The fore/hind limb ratio for stride time and stride length were not significantly different by 1.

For the peak pressure parameter, the fore/hind limb ratio were 1.60 (SD 0.15) and 1.45 (SD 0.28) and for activated sensors were 1.38 (SD 0.13) and 1.32 (SD 0.23) for Retrievers and Beagles, respectively (figure 1).

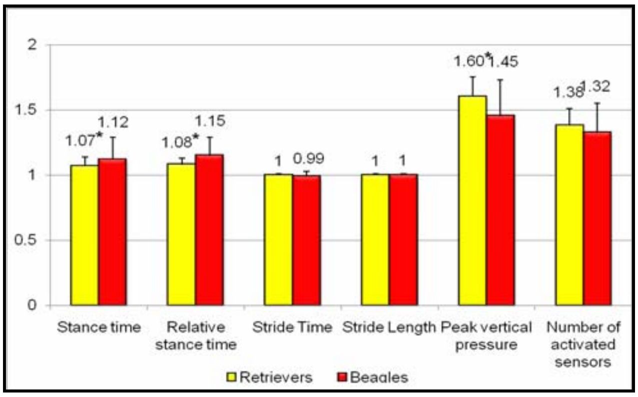

Fig. 1. The fore/hind limb ratio of the spatio-temporal parameters, the peak vertical pressure and the number of activated sensors of healthy large-breed adult and small-breed adult dogs at walk

Significant differences were observed in this ratio between the two groups for data values of stance time, relative stance time and peak pressure.

IV. Discussion

Recently, a human gait analysis tools have introduced GAITRite® system, a pressure mat, which measure spatio-temporal parameter, peak vertical pressure and velocity of walk. Combined with specialized quadruped-adapted software, this system can calculate these parameters for each limb at the same time and in the same conditions at one walk.

This portable system allowed recording the data of the four foot collateral, consecutive in a single pass so that an adequate amount of data for statistical comparisons can be collected by fewer passes over the walkway to compare with the force plate [6].

Studies recently assessed the concurrent validity of the GAITRite® system in humans with video-based analysis system [9]; paper-and-pencil and video-based methods [10]; a footswitch system [11]; a three-dimensional motion analysis system: Vicon-512 [12] and stopwatch–footfall count method [14], all of these reports demonstrated that the results of validity and reliability of this system for gait analysis were excellent. The same procedures had been done in dogs [20].

According the operator, tests were more difficult to perform on small breed dogs; large dogs seemed to be more quiet and regular than small dogs during walking over the walkway. Analysis of data seemed also easier and quicker for large dogs.

Using a 4.3 m long walkway, allowed numerous data to be collected even with large dogs (at least three and maximum five strides for a regular retriever) or small breed dogs (at least three and maximum eight strides for a beagle). Contrary to the force platform where data collection could be limited by the size of the dog: a large-breed dog with long stride tended to frequently contact the wrong place and the small-breed dogs were difficult to centre properly [8].

Most studies concerning gait analysis have been realized in large-breed dogs but very rarely in small-breed dogs especially for walking of healthy dogs so we did not find value references at walk for our study. In this study, the mean walking velocity was 1.09 (SD 0.18) m/s for the healthy large-breed dogs. This value corresponded well with the results of former studies for walking velocities that were around 1 m/s [2, 6, 8, 15, 21]. In the healthy small-breed dogs, the velocity was slightly higher than in the large-breed dogs (1.14; SD 0.36 m/s) but it was not significantly different.

The cadence for the small dogs was greater than for the large dogs (2.09; SD 0.22 strides/s and 1.60; SD 0.24 strides/s, respectively). Because of shorter legs smaller dogs, have small stride length and need to generate a greater limb frequency to achieve the same velocity as the larger dogs.

Titianova in 2004, had showed in humans, which the spatial and temporal parameters of gait closely related to the speed of walking, so the cadence and stride length were directly related with the velocity, meanwhile stance time and stride time were inversely related to velocity [13].

Mean stance times in forelimbs and hind limbs for large dogs were 0.45 (SD 0.08) s and 0.42 (SD 0.09) s, respectively. Our results were very close to Roush's kinetic results and Hottinger's kinematic results [2, 21].

The stance time and the relative stance time between both groups were significantly different. The research of Budsberg et al. (1987) has proven that stance time and body size were directly related [1]. Moreover, in other studies, stance time in the forelimbs and hind limbs had been shown to have a negative linear correlation with velocity [2-5].

Difference in body size and body weight explain significant differences when observed of the values of stride time; stride length; peak pressure and number of activated sensors between two groups. Budsberg in 1987 has shown that the ground reaction forces, stance phase and morphometric measurements were significant correlations [1].

The values of fore/hind limb ratio in both groups showed a more significant distribution on the forelimb rather than the hind limb for the stance time and relative stance time the peak pressure and the number of activated sensors. It corresponded well with the previous studies in healthy dogs at walk published by other authors [2, 5, 8, 15].

The ratio of fore/hind limb of the stance time was 1.07 (SD) for the large-breed. This result was slightly higher than ratio calculated from previous studies of Bockstahler (2007) and Hottinger (1996): 1.04 and 1.03, respectively.

The fore/hind limb ratio of maximal pressure was 1.60 (SD) for large dogs. Our values in large dogs were higher than the recent reports in healthy large-breed dogs were 1.38 [1] or 1.42 [15] or 1.46 for system platform and 1.38 for system pressure mat [6]. But this value in our study was similar to result 1.61 of Bockstahler (2007) [8].

Comparison of fore/hind limb ratio showed a significant difference between both sized groups for the stance time, relative stance time, and peak of pressure. And it seemed almost significantly different for the number of activated sensors. The forelimbs of small-breed adult dogs presented a fore/hind limbs distribution with less pressure (1.45/1.60) on forelimbs, but longer stance time (1.15/1.08) than the large-breed dogs, at walk.

To the author's knowledge, it has never been demonstrated before. Fore/hind limb ratio could be interesting to assess front or hind limb lameness but needs to be compared with same sized healthy dogs.

Symmetry between left and right legs was present in both groups for all parameters, and no significant variation in symmetry was found with size and weight variation for almost all parameters. However, authors noted that the standard variation for left and right symmetry in small breeds was slightly higher than large breed dogs for almost all parameters. Once again, difference in training could be advocated to explain such variation.

V. 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 previous studies, it could be concluded that the results were similar to those found in literature for large breed dogs which used other gait analysis devices.

For small dogs, with no previous study available, we have established a normative database for future pathologic study.

We observed in this study that large dogs seemed to be more regular, easier and quicker to analyse. Moreover small dogs parameters variation seemed slightly higher. In the first approach, the study of large dogs seems more reliable than small ones, but had required an adapted analysis device such as this long walkway.

The fore/hind limb ratio could be significantly modified with the size of the dog and needs to be taken into account for various sized dog gait analysis. This preliminary study needs to be followed by the establishment of a specific database for each breed and size.

However, the left and right symmetry did not seem to be modified by the size of the dogs, and were systematically present.

As already published, every lameness induces a modification of the symmetric pattern of the gait and according to this study, the use of the left/right limb symmetry and fore/hind limb ratio could help the clinician not only to determine and qualify the lameness but also allow reliable and accurate follow-up.

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