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Original Article

Gait analysis in clinically healthy small to toy breed dogs using a pressure plate

Yawon Hwang, Dongwook Kim, Gonhyung Kim*

Veterinary Medical Center, College of Veterinary Medicine, Chungbuk National University, Cheongju 28644, Korea

Locomotion can be investigated using visual locomotion scoring or computer-assisted techniques such as force plates or pressure plates. Although visual locomotion scoring is inexpensive, it is subjective and depends on observers. Conversely, computer-assisted techniques are objective and more sensitive than visual assessment. Many studies of gait in large breed dogs have been conducted using these techniques; however, there have been few investigations of small to toy breed dogs. Therefore, the purpose of the present study is to conduct gait analysis in small to toy breed dogs and to suggest normal reference ranges for clinical application. Twenty healthy dogs with no lameness or orthopedic pain weighing from 2 kg to 12 kg were used. The dogs were divided into two groups according to their weight, after which gait analysis was conducted using a pressure plate. The pressure force ratio between the forelimb and hindlimb was significantly lower in group 2 (mean 4.2 kg) than group 1 (mean 10.4 kg), while the stance time ratio between the forelimb and hindlimb tended to increase in group 2, but there was no significant difference. Other numerical values in group 2 tended to decrease, with some significant differences being observed. Overall, the results suggest that there are different gait features in small to toy breed dogs when compared with middle and large breed dogs.

Key words: gait analysis, pressure plate, force plate, small breed dogs, toy breed dogs

Introduction

Gait analysis which is the investigation of locomotion leads to better understanding of gait and therefore facilitates diagnosis of lameness and gait abnormality. Gait analysis technique ranges from rudimentary visual rating scales to complex computer-assisted motion detection equipment. In the last 30 years, technological advances in computer assisted gait analysis have aided the ability to quantitatively define spatio-temporal gait characteristics [1]. Force plates, which have been used since the late 1970s, are based on strain gauges and are now a standard method for evaluating the ground reaction forces [2] and being used in clinical area [3]. Pressure measurement systems can also be calibrated using simultaneous force plate measurements [4, 5]. Pressure plate and force plate analysis have become accepted techniques for accurate and objective evaluation of limb function in humans and animals, although the pressure plate has lower sensitivity than that of the force plate. Pressure plate gait analysis is a cost-efficient tool that can be used to identify causes of pain and disease, and facilitate healing. Gait analysis may be realized by many different techniques, including kinematic (motion) and kinetic (force) analysis [6]. Clinically, subjective scales such as numerical rating scales and visual analogue scoring scales can be used to describe the severity of lameness in dogs [7]. Although subjective evaluation of canine gait has been used for many years, it has some limitations such as perceiving minute details during the gait analysis [1]. Visual locomotion scoring is inexpensive and useful in clinical and research evaluation of gait when obtaining and maintaining a force plate is expensive, such as in private clinical practices [7]. However, scoring systems are subjective and tend to have varying results depending on the observers. In contrast, computer-assisted techniques are objective, sensitive, and more reliable than visual assessment. Various types of kinetic gait analyses have been used in veterinary medicine including the force plate, pressure-sensitive walkway, and treadmill systems [2, 8]. Pressure plate systems can also be applied to evaluate the kinetic parameters of the limbs of dogs, particularly the maximum force (pressure), stance and swing time, velocity and stride length. Pressure plate analysis can also detect

***Corresponding author:** Gonhyung Kim
Veterinary Medical Center, College of Veterinary Medicine, Chungbuk National University, Cheongju 28644, Korea
Tel: +82-43-261-3171, Fax: +82-43-261-3224, E-mail: ghkim@cbu.ac.kr

lameness or gait abnormalities that may not be detected by visual evaluation [9].

Many studies have investigated gait of middle to large breed dogs; however, few have considered small to toy breed dogs. Many toy breed dogs suffer from orthopedic problems such as patellar luxation, rupture of the cruciate ligament, and osteonecrosis of the femoral head. Therefore, in this study, gait analysis of small to toy breed dogs was conducted using a pressure plate to suggest normal reference ranges for clinical application, such as the maximum force (pressure), as well as to evaluate the usefulness of the pressure plate method as a substitute for force plate based analyses.

Materials and Methods

Animals

Twenty healthy adult small to toy breed dogs weighing from 2 kg to 12 kg were used. The dogs were clinically normal and client-owned dogs. Body weight was measured on an electronic scale.

Orthopedic Examination

Dogs with no lameness or orthopedic pain on examination and no history of musculoskeletal abnormalities were used. Dogs that showed no visible lameness during manipulation were considered normal.

Equipment Protocol

The gait analyzer system for veterinary medicine was developed to perform dynamic pressure measurements. Gait Analyzer^{TM} (Tech Storm Co., Ltd., Daejeon, Republic of Korea) was used to measure the dog's gait (Figure 1). The Gait Analyzer system can analyze pressure by region while the participants walk on a 1,200 × 540 mm and 2.5 mm thick plate. The sensor size is 0.8 × 0.8 cm, and the sensing area is 1,152 × 384 mm. The sensor is a film-type pressure sensor consisting of a 7,500-cell matrix array with a frequency of 30–100 Hz. Gait was measured more than six times, and successful trials were obtained. The measurement values were analyzed using the Gait Analyzer application software.

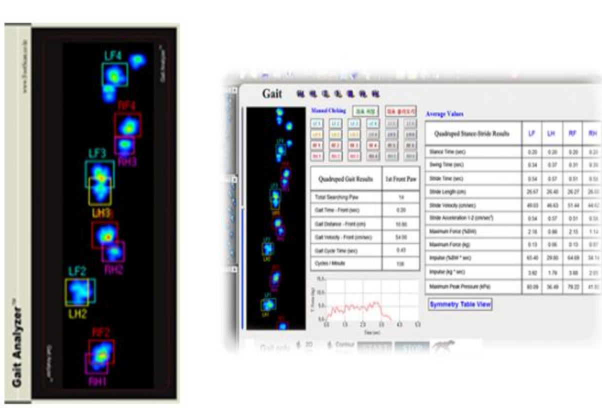

Fig. 1. Pressure plate gait analyzer system (Tech-storm) and measurement software

Experimental Design

Animals were divided into two groups of 10 dogs each by body weight. Group 1 consisted of dogs 9.5–11.5 kg (10.4 ± 0.5), and group 2 consisted of dogs 2.5–5.7 kg (4.2 ± 1.6). Body condition scores of dogs were 4–6 on a scale of 1–9 [10]. Dogs were acclimated to the pressure plate before data collection began and walked across the force plate until they appeared to be comfortable and relaxed. Six valid evaluations were collected for each dog, and each limb was recorded. The mean data of each dog were obtained from 4 available records for statistical analysis. Pressure forces, stance and swing times, and stride length were used to calculate the percentage of distribution of the dog's weight among the four limbs [11]. The walking velocities of the animals were not exactly controlled, but animals were walked on leashes at a rate that minimized gait changes caused by velocity under the guidance of handlers.

Statistical Analysis

Group differences were assessed by Student's t-test. All analyses were conducted using the SPSS for Windows software, version 12.0 and a $p<0.05$ was considered significant. All data were expressed as the means ± standard deviation (S.D.).

Results

Pressure Plate Gait Analysis

The pressure force ratio between the forelimb and hindlimb in group 1 (1.39 ± 0.07) differed significantly from that of group 2 (1.12 ± 0.10) (Table 1). The velocity of group 1 was 120.35 ± 37.98 cm/sec, while it was 94.59 ± 27.83 cm/sec in group 2.

The forelimb stance time was 0.19 ± 0.01 and 0.16 ± 0.03, while the hindlimb stance time was 0.18 ± 0.02 and 0.14 ± 0.04 in group 1 and group 2, respectively. The ratio between the forelimb and hindlimb was 1.11 ± 0.13 (group 1) and 1.18 ± 0.17 (group 2). The forelimb swing time was 0.31 ± 0.11 and 0.18 ± 0.17, while that of the hindlimb was 0.31 ± 0.16 and 0.20 ± 0.05 in group 1 and group 2, respectively. The ratio between the forelimb and hindlimb was 1.05 ± 0.23 (group 1) and 0.88 ± 0.11 (group 2), and the stride length was 53.30 ± 6.45 (group 1) and 31.92 ± 7.49 (group 2). The forelimb stance time, forelimb swing time, and stride length differed significantly between groups (Table 2). There were no differences between the left and right limbs.

Discussion

In clinical settings, the reliable and validated objective evaluation of locomotion or lameness is necessary and important. In a previous study, no significant relationships were observed between subjective lameness scoring systems and force plate analysis [7]. Although setting and maintaining a force plate system for gait analysis is expensive and requires a large space, this method is more accurate and reliable than subjective scoring scales.

The force plate can evaluate variable values, including peak vertical and horizontal forces, vertical impulses, strain within various tissues, rated loading, stride time, stride length, stance time, and pressure distribution of the paw [1, 6]. Although it is not as sensitive as the force plate method, the pressure plate method can be used as an alternative for gait analysis because it has relatively lower costs and is relatively easy to install and move.

In this study, the orthopedic normality of dogs was evaluated by physical examination and visible locomotion. Some studies have used radiographic examination as a standard for evaluation of degenerative joint diseases [11-13]. However, the correlation between radiographic signs of osteoarthritis and limb function is reportedly poor [14]. Moreover, in a study using force platform analysis, Gordon et al. found no correlation between the radiographic osteoarthritis score of dogs suffering from stifle osteoarthritis and several vertical ground reaction forces [15]. The present study was not conducted to confirm improvements, but rather to assess normal locomotion. Therefore, radiographic evaluation should be included in future studies to rule out degenerative joint diseases.

Many studies describing ground reaction forces in clinically normal dogs have been performed using single force plate systems [11-13, 16]. However, most previous studies have evaluated the gait of large breed dogs weighing over 20 kg [2, 8-9, 11, 17], while few have investigated the gait of normal small to toy breed dogs weighing less than 10 kg. Therefore, the result of the present study is thought to be meaningful to establish normal range of small breed dogs' gait and to confirm that the pressure plate is useful.

In this study, the pressure force ratio between the forelimb and hindlimb decreased as body weight decreased with those of group 1 differing significantly from those of group 2. In contrast, the stance time ratio between the forelimb and hindlimb tended to increase with decreasing weight, but this difference was not significant. All numerical values tended to decrease, with several groups being significantly lower in group 2 than group 1.

Previous studies revealed that body weight, body size, velocity and ground reaction forces were related [18, 19]. The use of kinematic analysis and force plates has been validated as a useful tool in veterinary medicine [1]. Use of these force quantification for healthy dogs may yield valuable information for evaluation of an animal before and after surgical or medical treatment for a given pathologic condition, and generated data may provide objective answers for determining therapeutic success or failure [11].

Further studies are needed because of the small number of dogs in this study. Nevertheless, different gait features were shown to exist in small to toy breed dogs when com-

Table 1. Maximum pressure ratio of forelimb to hind limb and gait velocity

Groups	Body weight (kg)	Fore/hind limb ratio	Velocity (cm/sec)
Group 1 (n=10)	10.4 ± 0.5	1.39 ± 0.07	120.35 ± 37.98
Group 2 (n=10)	4.2 ± 1.6	1.12 ± 0.10*	94.59 ± 27.83*

*$p<0.05$ compared with Group 1

Table 2. Stance time, swing time, and stride length

Groups	Stance time			Swing time			Stride length (cm)
	Fore (s)	Hind (s)	Ratio F/H	Fore (s)	Hind (s)	Ratio F/H	
Group 1 (n=10)	0.19 ± 0.01	0.18 ± 0.02	1.11 ± 0.13	0.31 ± 0.11	0.31 ± 0.16	1.05 ± 0.23	53.30 ± 6.45
Group 2 (n=10)	0.16 ± 0.03*	0.14 ± 0.04	1.18 ± 0.17	0.18 ± 0.17*	0.20 ± 0.05	0.88 ± 0.11	31.92 ± 7.49*

*$p<0.05$ compared with Group 1

pared to large dogs. Moreover, the results of the present study indicate the potential for use of the pressure plate instead of the force plate for gait analysis of small to toy breed dogs.

As veterinary rehabilitation becomes more popular, locomotion analysis will be utilized to a greater extent [20]. Therefore, it is important to conduct additional studies to normalize the technique as well as to enable categorization by body weight of gait analysis using pressure plate or force plate systems.

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ORCID

Gonhyung Kim, http://orcid.org/0000-0002-9384-4741

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