Two-Dimensional Kinematic Motion Analysis of Hip, Stifle and Tarsal Joints in Chihuahuas during Trotting on Treadmill

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Introduction
The traditional scale for gathering gait analysis data is to do a visual gait analysis (VGA) that relies on the observer being able to assess the body’s movements during the rapidly repeating gait cycle. This subjective measurement is carried out by the personal impression of attending clinician. However, subjective lameness scoring scales may not accurately reflect lameness gait analysis in dogs (6). The disagreement among investigators for scoring mild lameness in running horses emphasizes that more objective measurement should be used for quantifies lameness (11). Kinematic is a science for describing of body motion, irrespective influence of force and weight. The field of this study is referred as the "geometry of motion". Kinematic motion analysis is popular tool using in canine clinical practice for objective locomotor assessment. A validated method of gait analysis is three-dimensional (3D) optoelectronic motion analysis, which uncommon used in clinical practice because it is an expensive tool and requires the knowledge and expert person in order to operate the system leading to the limited use in the research field. Therefore, two-dimensional (2D) video-based motion analysis system is a suitable tool used for gait analysis. This equipment is easier to implement than 3D system and does not require expert person. Previous studies of kinematic gait analysis in various large breed dogs such as Belgian Shepherd, Greyhound, Labrador retriever and German shepherd show various posture and joint movement due to various body conformations (2,3,4,7,10). Breed specific kinematic studies adapted to breed conformation standards are necessary to explain how particular conformational features may affect the musculoskeletal function. However, there is limit objective information of joint movement during gait in small breed dogs. This study presents the 2D video based system for gait analysis in sagittal plane with the small breed dogs during trotting on treadmill.

Materials and Methods
Five healthy Chihuahuas (two males, three females) presented at Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University were included in this study. Age and weight were recorded. All dogs underwent thorough orthopedic, neurologic and radiographic examination were considered clinically sound. The standard protocol was accepted by the Laboratory Animal Ethics Committee of the Faculty of Veterinary Science, Chulalongkorn University (Approval No.163121), Bangkok, Thailand. The 2D video-based kinematic was recorded the movement of the dogs by using two cameras (AS200V, Sony Corporation, Japan) with resolution 1280x720p at 120fps mode. Two cameras were placed 0.5 m from both sagittal plane of treadmill. The video system was calibrated by placing stationary calibration frame which known coordination on the treadmill upon spherical non-reflexive markers (Ø 10 mm). The markers were tagged to the skin on lateral aspect of both pelvic limbs over 5 specific anatomical landmarks (Figure 1). The marker locations were verified and replaced every session by one researcher. The dogs were trained in order to familiar with trot on treadmill (1.11 m/s) before they were evaluated by using adapted protocol (7, 9). Videos were recorded for 3 sessions with 3 minutes in each session and 3 valid trials used per session. Five completed strides were analyzed for each trial. The marker coordinating data were extracted by using purpose designed freeware motion analysis software (Kinovea program experimental version 0.8.24).

Figure 1 Anatomical landmarks (target) and anatomical coordinate tracking of each marker (dash line) during trotting on treadmill
The joint angular displacements were determined for hip, stifle and tarsal joints. A stride contains stand phase and swing phase. The active range of motion (AROM) was calculated by subtracting the maximal flexion angle (MFA) from the maximum extension
angle (MEA) in every stride. Statistical analysis was performed using SPSS statistics version 22. The data variation was investigated using the Shapiro-Wilk test. The kinematic data were reported as mean ± SD or median (range).

**Results and Discussion**

Age of the dogs ranged from 1 to 3 years (1.92 ± 0.62 years), and body weight ranged from 2.40 to 4.17 kg (3.2 ± 0.55 kg). No significant differences were found between right and left limbs in all kinematic variables. The dogs were observed at the trot. The gait pattern is considered to be a symmetrical gait in which the movements of one side of the body with mirror the movements of the opposite side. The average angular displacements of hip stifle and tarsal joints are showed on Table 1. The parametric differences were observed between this study with the other (9). The main limitation of 2D analysis is when a motion is taking place in a plane not parallel to the calibration plane causing the recorded motion analysis might not be accurate. For this reason, our study used spherical markers instead of flat markers, to decrease the limitation of 2D analysis.

**Table 1 Average joint angular displacement**

<table>
<thead>
<tr>
<th>Joint</th>
<th>MEA</th>
<th>MFA</th>
<th>AROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip</td>
<td>140.76±4.72</td>
<td>122.08±4.23</td>
<td>18.68±1.527</td>
</tr>
<tr>
<td>Stifle</td>
<td>166.21(22.87)</td>
<td>119.18(41.89)</td>
<td>52.64±9.11</td>
</tr>
<tr>
<td>Tarsus</td>
<td>156.70(42.85)</td>
<td>108.65(47.34)</td>
<td>49.42±7.81</td>
</tr>
</tbody>
</table>

A graph of angular displacement versus time shows in Figure 2. Each joint had a typical pattern of extension and flexion. The beginning of stance phase was determined by the MEA of stifle, and the beginning of swing phase was determined by the MEA of tarsus. At trotting, hip joint extended slowly over the stance phase and return to flexed during swing phase. Stifle joint flexed gradually from the initial stand phase to the mid-swing phase then extended sharply until the terminal swing phase, corresponding to the initial contact of stance phase. Tarsal joint extended slightly during stance phase then suddenly flex at initial of swing phase. At the mid-swing phase, the tarsal joint extended rapidly until the terminal swing phase. The angular displacement patterns of these joints are similar to the patterns in some large breed dogs (1,3,7,10). However, it is important to recognize the limitations of our study. Movement of skin and muscle over anatomical landmark may be considerable artifact during kinematic analysis of pelvic limb (5). The muscle strength is effect to angular displacement as reported in previous study (8). We used a simple 2D camera system (high framerate digital video camera with free software) as the basic application for evaluating current theory in gait analysis. This equipment is reasonable cost and practically in a clinical study. This 2D kinematic system could aid a value for veterinarian orthopedist evaluation to improve the VGA. In conclusion, the results of this study contribute to the knowledge of the joint locomotion in small breed dogs. Further research should be encouraged to compare these baseline kinematic data with the same morphometric characteristics and the same protocol to evaluate pathologic limb movements.

**Figure 2** Angular displacement of (a) Hip joint, (b) Stifle joint, (c) Tarsal joint

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**References**