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Kinematics of healthy American Pit Bull Terrier dogs

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Abstract: A visual clinical gait analysis is useful, however, it may overlook small, but important, details about the movement, as well as differences between the normal and pathological locomotion. The branch of mechanics that describes the spatial and temporal components of motion is called kinematics, providing quantitative data regarding linear and angular motion. The objective of this study was to establish kinematic gait data of healthy American Pit Bull Terriers and to contribute to the understanding of the locomotion. We evaluated the articular and pelvic angles, and the spatiotemporal variables for walking and trotting from eleven dogs with no previous history of joint and musculoskeletal diseases. Twenty reflective markers were positioned at the anatomical points of interest. The animals walked and trotted in a linear space, led by the same researcher. The kinematic data were collected through optoelectronic cameras and analysed by motion analysis software. The movements analysed during the gait phases were the flexion, extension, range of motion (ROM), angle at the moment of the support phase, stride length and velocity. Comparing the angles between walking and trotting, there were more expressive differences for the pelvic limb joints. There was no difference between the left and right sides at all of the joint angles of the pelvic limbs during walking and trotting. Therefore, the movement of the pelvic limb is symmetrical in both trotting and walking. Our results present reference values for healthy American Pit Bull Terriers, having clinical relevance for studies of dogs with musculoskeletal diseases.

Keywords: canine gait; joint angles; kinetics; musculoskeletal system

A kinematic evaluation is the study that describes the spatial and temporal components of motion, and involves the position, velocity, and acceleration of a body, regardless of the forces that cause movement (Hamill and Knutzen 2008).

The cycle of movement when walking includes the support of two or three limbs, and at trot, there is the support of two limbs, with diagonal pairs (DeCamp 1997). A clinical gait analysis (visual observation) is useful, but not very precise, whereas a kinematical quantitative analysis covers a more efficient evaluation, calculating distance variables and angular variables (Hamill and Knutzen 2008; Gustas et al. 2013).

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The motion of a kinematic analysis may reveal details about the movement, as well as the differences between a normal and pathological locomotion.

The American Pit Bull Terrier is a large breed used as a companion dog as well as a working dog. This breed, like other large breeds, may present with musculoskeletal changes such as hip dysplasia, elbow dysplasia, shoulder subluxation, biceps tenosynovitis, ruptured cruciate ligaments, among other disorders such as cauda equina syndrome and obesity, which also promote locomotion alterations (Bach et al. 2015).

Pain, muscle weakness, and an abnormal range of motion (ROM) are some of the important factors that may affect the gait. In dogs, the effect of pain on the gait causes a decrease in the support phase and less contact with the floor. Weakness affects the movement, increases or decreases the joint when the muscle usually contracts. Compensation usually occurs in other joints (DeCamp 1997). Thus, the biomechanics can provide important information in order to quantify normal and abnormal movements, including the function of the limbs and the body as a whole (Angle et al. 2012).

Therefore, this study aimed at establishing kinematic data on the gait of clinically healthy dogs of the American Pit Bull Terrier breed and to contribute to the understanding of the locomotion.

MATERIAL AND METHODS

Animals

We studied eleven American Pit Bull Terrier dogs, selected from tutors and the Hoffmann Pit kennel, located in Londrina, Paraná, Brazil.

Four of the animals were females and seven were males, aged between 2 and 6 years, and without any previous history of joint or musculoskeletal diseases.

All the animals were clinically evaluated (general physical and orthopaedic examination), and a body condition score (BCS) between 4 and 6 was established by direct inspection and palpation, described by Laflamme (1997). Dogs with changes, such as lameness and joint pain, would have been excluded from the study.

This study was approved by the Ethics Committee of the State University of Londrina (Protocol No. 6321.2016.68).

Data collect

The study was conducted at the Laboratory of Applied Biomechanics in the Department of Sports Sciences at the State University of Londrina. Each dog had twenty spherical reflective markers (1.5 cm in diameter), positioned on the skin (3M adhesive tape) over the spine of the scapula (acromion), major tubercle of the humerus, lateral epicondyle of the humerus, fifth metacarpal, iliac crest, major femoral trochanter, femoral condyle, lateral malleolus and fifth metatarsal head, on both sides (Figure 1A). These markers were analysed in two moments, walking and trotting, always guided by the same individual, in a seven-metre linear path. The acquisition of the three-dimensional kinematics was performed by six cameras (Optitrack®; Leyard, Oregon, USA), with a sampling frequency of 240 Hz.

Ten attempts were recorded for each dog, and the cycles of motion were selected in which all the markers could be identified. The system created three-dimensional coordinates, in which the X axis represented the craniocaudal displacement, the Y axis represented the medium-lateral and the Z axis represented the vertical one.

The markers were reconstructed using Motive Body v1.8.0 software (Leyard, Oregon, USA). The three-dimensional coordinates of each of the markers were smoothed by a third-order Butterworth low-pass digital filter with a 6 Hz cut-off frequency, defined after the spectral analysis. Matlab® software was used to implement the kinematics equations. The absolute articular angles of flexion and extension were evaluated for the joints of the scapula and the iliac crest.

For the joints of the shoulder, elbow, carpal, hip joint, knee and tarsus, the relative angles were quantified (Figure 1B).

The variables identified were the maximum and minimum angles of each joint, the range of motion (defined as the subtraction between the maximum and minimum values) and the angle at the first moment of the support phase. The spatiotemporal variables quantified were:

a) the stride length (defined as the distance travelled by the dog during the movement cycle, considering the three-dimensional average coordinates between the points of the scapula and crest), normalised by the dog height and

b) stride speed.

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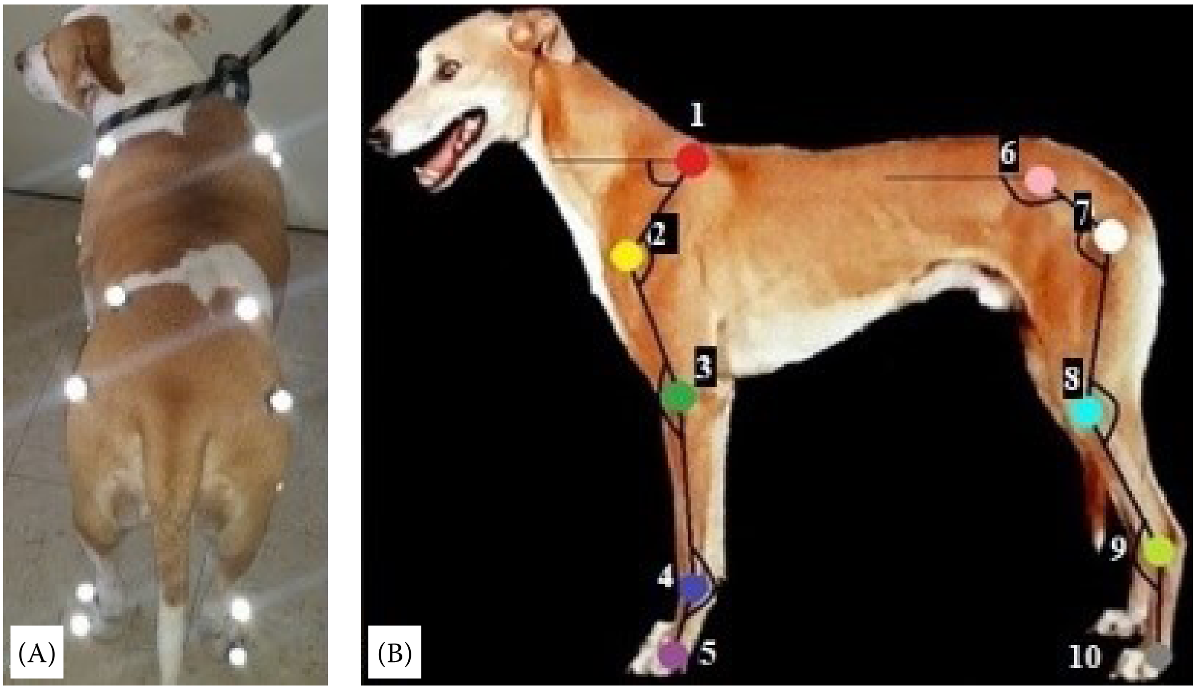

Figure 1. Reflective markers at the anatomical points of interest
Source: Personal archive (A); Done et al. (2010) adapted (B)
Joint angles analysed: 1: Scapula; 2: Shoulder; 3: Elbow; 4: Carpal; 5: Metacarpal; 6: Iliac crest; 7: Hip (coxal); 8: Knee; 9: Tarsus; 10: Metatarsus

Statistical analysis

The analysed variables did not present normality by the Lilliefors test, $P < 0.05$. Thus, the data were evaluated by non-parametric tests and the descriptive statistics were presented in medians and quartiles. On the other hand, the comparison between the angles observed in the right limbs and in the left limbs was performed by the Mann-Whitney U test ($P < 0.05$) at two moments: during walking and during a trot. All the analyses were performed in the Statistica v13.0 program (Statsoft, Brazil).

RESULTS

In the evaluation of the spatiotemporal values, the average length of the stride was 1.41 ± 0.12 m/m with an average speed of 1.17 ± 0.17 m/s during walking. The length for the stride during trotting was 1.98 ± 0.22 m/m with a mean velocity of 2.04 ± 0.33 m/s. There was less variability in the length and mean velocity of the gait during the walk, indicating a more homogenous pattern when compared to the length and average speed of the gait during the trot.

Comparing the angles of the thoracic limb, we found that the scapula ROM was greater $P < 0.05$ during the trot when compared to the walk. The extension angles and the shoulder support phase were greater ($P < 0.05$) during the walk compared to the trot. However, the shoulder ROM was greater ($P < 0.05$) in the trot in relation to the walk. The elbow flexion angle was bigger ($P < 0.05$) during the walk when compared to the trot. The extension angles and of the carpal ROM were greater ($P < 0.05$) during the trot when compared to the walk. In turn, the flexion angle of the carpus was higher ($P < 0.05$) during the walk (Figure 2).

When comparing the walk and trot angles of the pelvic limbs, the differences in the angles between the walk and the trot were more expressive, with alterations in most of the analysed anatomical regions, except for the extension and support angles of the knees.

For the iliac crest joint, the extension, flexion and support angles were higher ($P < 0.05$) during the trot. However, the ROM angle was higher during the walk. For the hip (coxal) joint, the angles of extension, ROM and support were higher during the walk. However, the flexion angle was higher during the trot. The knee flexion was greater dur-

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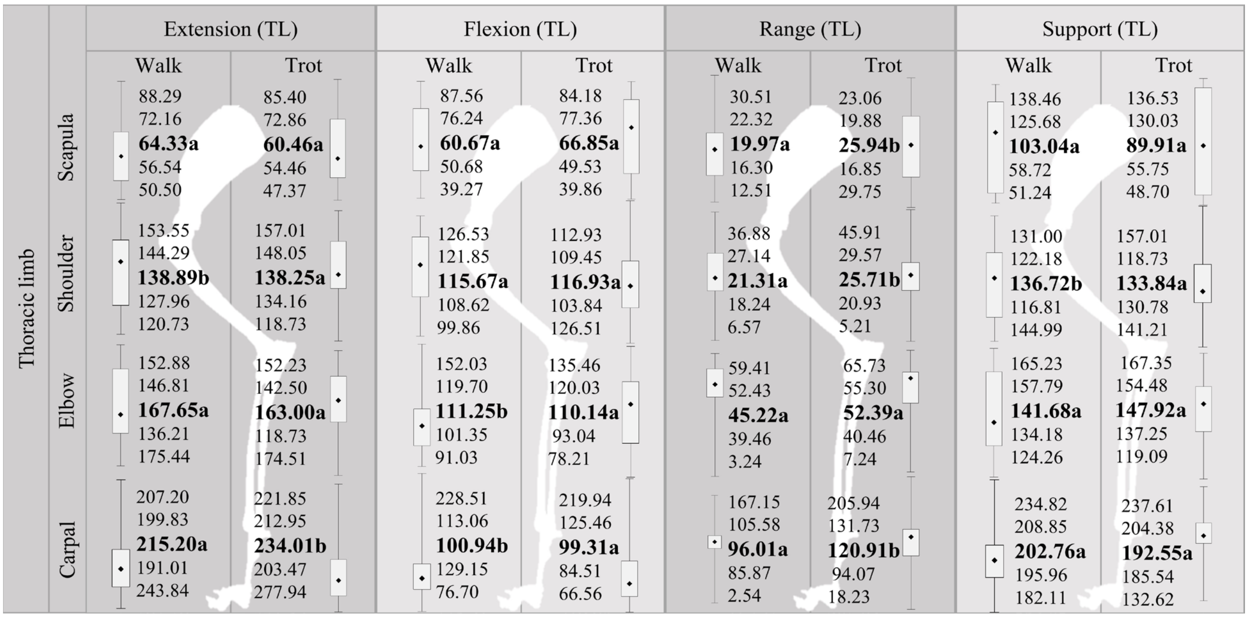

Figure 2. Medians, quartiles and minimum and maximum values of the extension, flexion, ROM and support angles of the thoracic limb (TL) during walking and during trotting. The medians with the same letters did not differ in the Wilcoxon test, at $P < 0.05$

ing the walk, while the ROM was greater in the trot. For the tarsus, the extension and ROM angles were higher in the trot, while the flexion angle was higher during the walk (Figure 3).

The angles of the right and left thoracic limbs were compared during the walk. In the scapula, only the ROM was greater ($P < 0.05$) in the left limb when compared to the right one (Table 1). There was no difference between the left and right sides at all of the angles in all the regions of the pelvic limbs.

When comparing the angles of the right and left thoracic limbs during trotting, in the support angle, the angle of the right shoulder was higher when

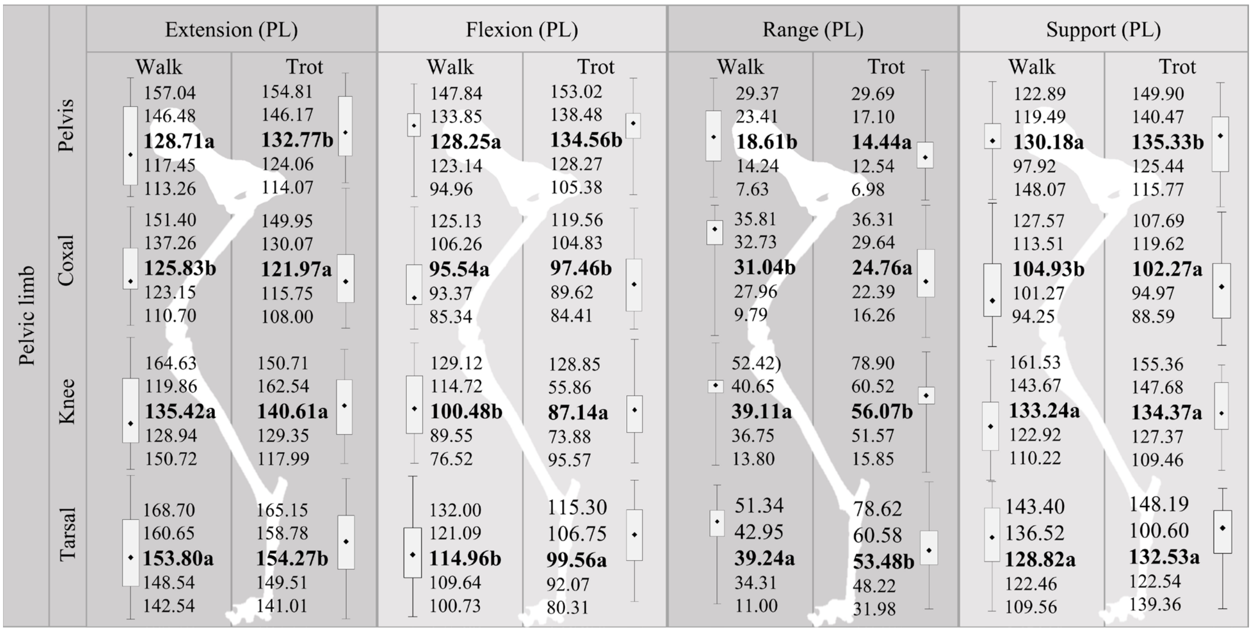

Figure 3. Medians, quartiles and minimum and maximum values of the extension, flexion, ROM and support angles of the pelvic limb (PL) during walking and during trotting. The medians with the same letters did not differ in the Wilcoxon test, at $P < 0.05$

Table 1. Medians (med), quartiles (Q25–Q75) and minimum (min) and maximum (max) angles of extension, flexion, amplitude and support of the right and left thoracic joints during walking

		Scapula		Shoulder		Elbow		Carpal	
		R	L	R	L	R	L	R	L
Angle of extension	med	65.03[a]	60.31[a]	143.95[a]	138.45[a]	152.03[a]	153.45[a]	205.77[a]	213.28[a]
	min	50.50	54.22	120.73	121.02	136.21	146.05	197.01	191.01
	max	88.29	81.21	153.55	144.99	175.44	169.91	236.30	243.85
	Q25	61.83	56.05	128.90	125.91	143.71	149.52	200.40	199.83
	Q75	70.35	72.16	147.16	140.65	169.89	165.74	210.75	217.55
Angle of flexion	med	60.67[a]	54.05[a]	116.74[a]	112.03[a]	116.29[a]	110.82[a]	106.98[a]	114.64[a]
	min	47.60	39.27	107.39	99.86	91.03	93.96	91.80	76.70
	max	87.56	81.04	125.23	126.53	151.86	152.03	228.51	197.17
	Q25	52.39	50.46	113.45	104.51	100.68	105.11	95.97	104.33
	Q75	75.49	76.24	119.12	122.04	123.31	116.50	134.46	124.91
ROM	med	17.33[a]	21.06[b]	23.77[a]	20.21[a]	43.33[a]	46.44[a]	100.41[a]	96.01[a]
	min	12.51	14.86	6.57	17.33	3.24	7.37	2.54	9.63
	max	30.51	27.48	36.88	28.13	59.41	56.92	114.78	167.15
	Q25	15.62	19.39	18.24	18.46	38.80	41.49	77.10	92.42
	Q75	20.46	23.38	28.77	24.29	52.68	49.96	107.69	99.82
Support phase	med	56.79[a]	56.97[a]	134.40[a]	129.06[a]	143.98[a]	144.52[a]	203.31[a]	202.48[a]
	min	51.24	41.54	119.82	116.81	124.27	125.51	193.16	182.11
	max	68.34	78.17	144.02	144.99	164.05	165.23	234.82	215.14
	Q25	54.95	50.68	122.54	122.18	130.58	136.42	197.57	193.73
	Q75	61.54	60.23	136.72	135.30	157.77	158.88	208.54	209.24

L = left; R = right; ROM = range of motion; [a,b]The results showed a significant difference

Table 2. Medians (med), quartiles (Q25–Q75) and minimum (min) and maximum (max) angles of extension, flexion, amplitude and support of the right and left thoracic joints during trotting

		Scapula		Shoulder		Elbow		Carpal	
		R	L	R	L	R	L	R	L
Angle of extension	med	65.89[a]	59.89[a]	144.05[a]	135.53[a]	149.87[a]	155.19[a]	215.70[a]	224.59[a]
	min	47.37	50.04	129.05	118.73	132.23	126.31	205.94	203.47
	max	85.40	81.60	157.01	151.95	174.51	165.85	283.74	277.11
	Q25	54.67	54.25	134.27	128.59	141.71	145.37	211.32	218.15
	Q75	70.83	77.32	148.30	141.78	171.92	162.28	247.24	235.74
Angle of flexion	med	61.11[a]	63.85[a]	113.19[a]	113.52[a]	117.38[a]	109.73[a]	91.74[a]	102.88[a]
	min	47.04	39.86	103.84	103.91	78.21	89.20	66.60	71.17
	max	84.18	82.66	126.51	119.42	135.46	123.94	193.46	219.94
	Q25	49.50	49.57	109.44	109.45	86.24	100.56	83.69	84.77
	Q75	77.91	76.67	119.03	116.68	124.71	113.50	130.95	116.62
ROM	med	24.09[a]	23.23[a]	27.10[a]	21.69[a]	53.46[a]	51.48[a]	122.34[a]	120.91[a]
	min	16.85	17.75	18.89	5.21	10.85	7.24	28.81	18.23
	max	29.75	29.20	45.91	37.96	65.73	59.80	203.74	205.94
	Q25	20.28	19.83	24.88	18.58	41.68	39.25	87.78	100.37
	Q75	26.12	26.49	29.27	34.93	56.77	53.98	139.56	133.88
Support phase	med	51.77[a]	52.32[a]	137.63[b]	133.24[a]	149.87[a]	147.15[a]	187.25[a]	204.29[b]
	min	47.04	43.47	124.39	118.73	119.10	120.20	179.02	179.32
	max	63.67	63.85	157.01	150.73	169.32	156.09	237.61	219.94
	Q25	48.70	50.08	132.98	128.59	137.04	137.47	184.49	198.13
	Q75	58.65	57.67	143.49	135.15	164.25	153.31	191.63	206.49

L = left; R = right; ROM = range of motion; [a,b]The results showed a significant difference

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compared to the left, while the angle of support of the left carpus was higher (Table 2). There was no difference between the sides at all of the angles in all the regions of the pelvic limbs.

In the joint movement of the limbs of the dogs, the maximum angular values occurred during the extension and the minimum angular values occurred during the maximum flexion (Figures 4, 5, 6 and 7).

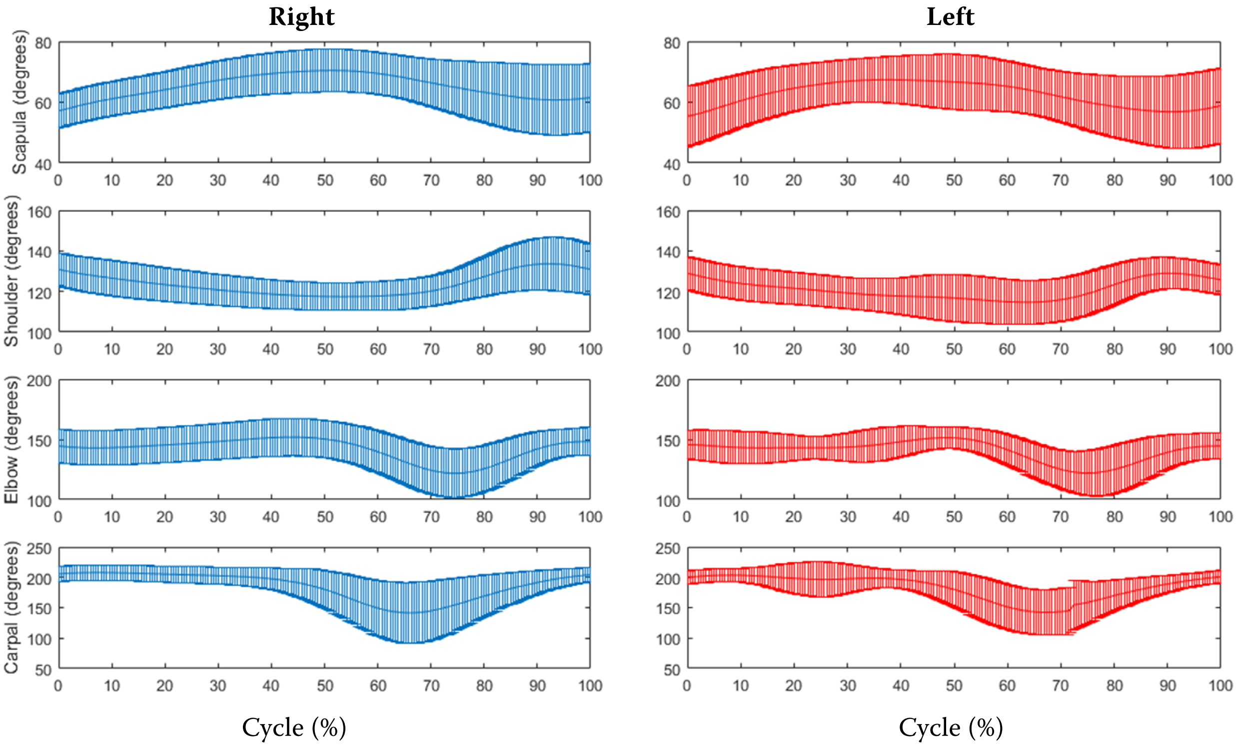

Figure 4. Joint movement of the thoracic limbs of the dogs studied during walking

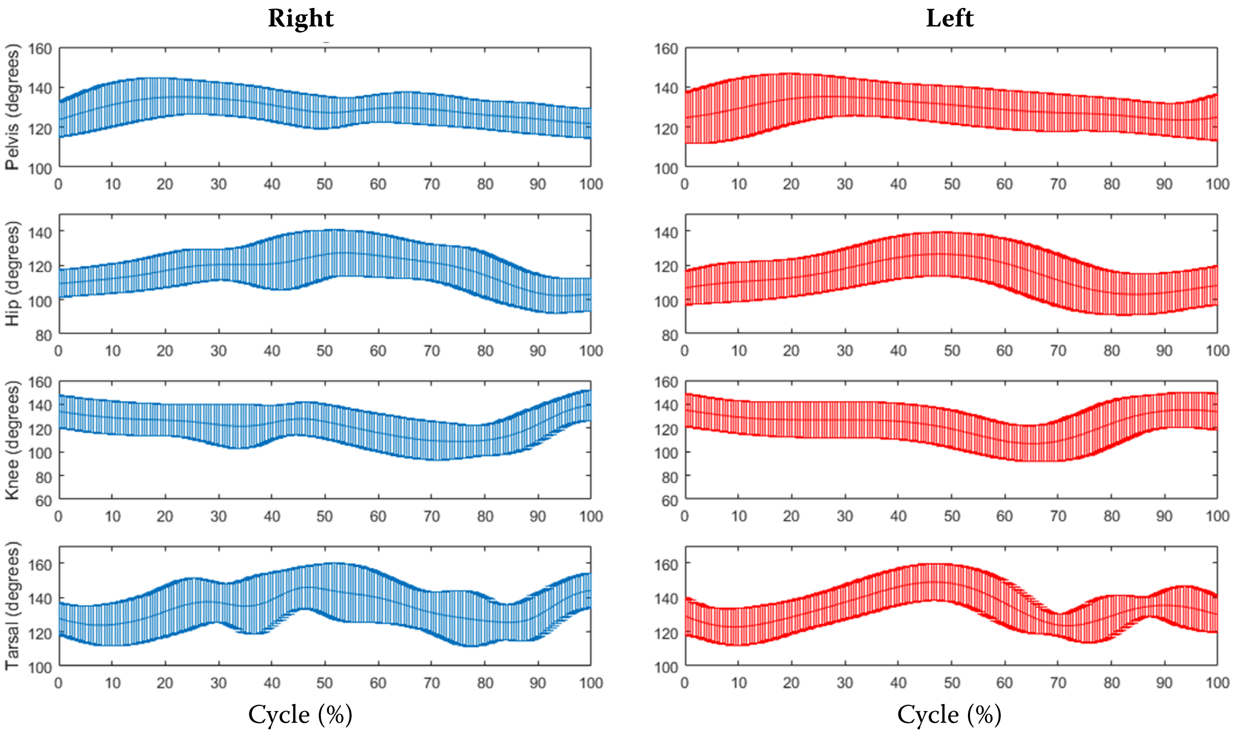

Figure 5. Joint movement of the pelvic limbs of the dogs studied during walking

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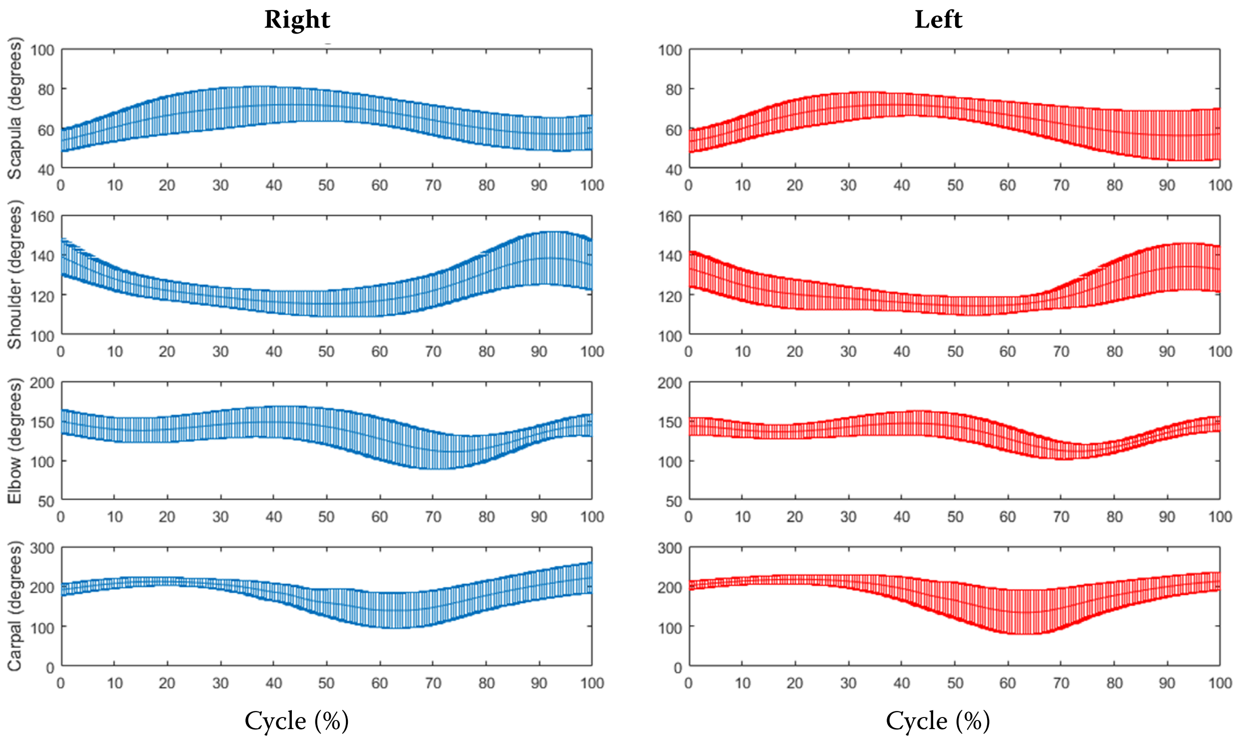

Figure 6. Joint movement of the thoracic limbs of the dogs studied during trotting

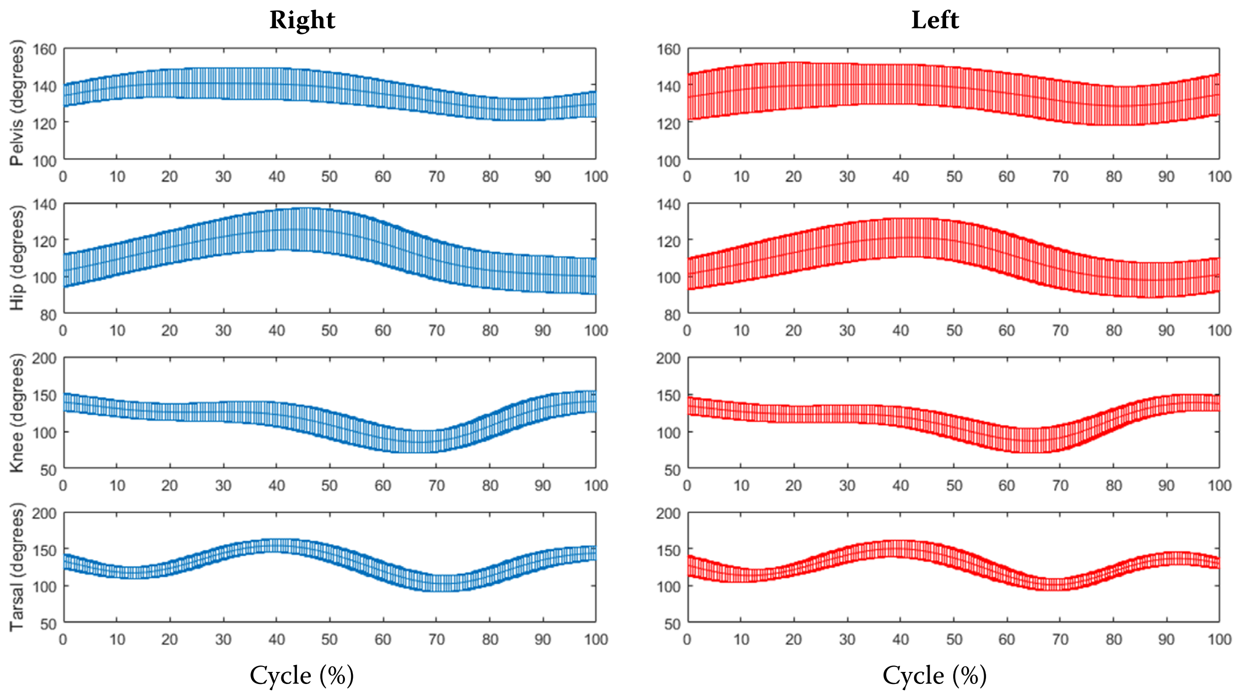

Figure 7. Joint movement of the pelvic limbs of the dogs studied during trotting

DISCUSSION

The objective of this study was to establish the kinematic gait data of healthy American Pit Bull Terriers and to contribute to the understanding of the locomotion. The selected dogs were clinically healthy and had no previous history of joint or musculoskeletal diseases, were of both sexes, being the criteria similar to those described by Angle et al. (2012).

The American Pit Bull Terrier was selected because it is large in size, which is common in presenting with musculoskeletal changes that result

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in locomotion alterations (Bach et al. 2015). In addition, the criteria for being shorthaired dogs (favouring marker fixation), the ease of manipulation of the animals, being docile to humans and the lack of kinematic studies related to the breed were also taken into account.

A kinematic gait analysis in healthy dogs has been addressed by some authors (Jarvis et al. 2013; Silva et al. 2014; Kopec et al. 2018). However, none of them addressed the gait in healthy American Pit Bull Terriers. Agostinho et al. (2011) suggest that each breed must have a specific database.

Most of the kinematic studies used a gait treadmill with standard values between 1.80 and 2.22 m/s (Poy et al. 2000), which makes the spatio-temporal values found in our study unprecedented for the American Pit Bull Terrier breed, without the use of a treadmill. A recent study (Jarvis et al. 2013) evaluated healthy dogs of different large breeds, observing a mean length of 1.95 ± 0.28 m/m, and a velocity of 2.4 m/s in the trot. These values are similar to the ones presented in our study.

Comparing the joint angles of the pelvic limbs, there was no difference between the right and left sides in all the regions, both for walking and trotting, corroborating the results of other studies comparing the extension and flexion angles (Gillette and Zebas 1999). Therefore, the movement of the pelvic limb was symmetrical, a relevant fact for kinematic studies of dogs with musculoskeletal diseases.

Comparative studies between Labrador Retrievers and Greyhound dogs, reported significant differences in the hip biomechanics. The ROM of the pelvic limbs and the stride length of the Greyhound were greater than the values of the Labrador Retriever, which indicates that the body factors specific to each breed influence the animal's movement (Hottinger et al. 1996; Bertram et al. 2000).

In our study, the mean values for the carpal joints were 191.4 ± 13.7 degrees (right side) and 201.7 ± 10.3 degrees (left side). For the iliac crest joints, they were 134.2 ± 5.6 degrees (right side) and 133.4 ± 12.1 degrees (left side). The degrees we reported are different from a previous study (Jarvis et al. 2013), which reported 211.6 ± 10 degrees (carpal joint) and 112.1 ± 10.3 degrees (crest joint). The greatest value in the range of motion was found for the carpus joint, both at walk (right: 79.6 degrees, left: 90.9 degrees) and at a trot (right: 120.2 degrees, left: 110.2 degrees), corroborating the information from with Jarvis et al. (2013), who also reported a greater range of motion for the carpal joint (323 degrees). However, the difference in the ROM values between the studies is noteworthy. The authors did not standardise a specific breed, which may justify the differences between the studies.

Kopec et al. (2018) compared the kinematics of healthy dogs, of different breeds, with an average body weight of 22.3 ± 1.0 kg, during trotting. They found that the elbow joint reached a maximum extension at the end of the support phase, that is, immediately before toe-off, with the mean values of the ROM and maximum extension for the elbow joint being 65.81 ± 7.48 degrees and 132.03 ± 11.49 degrees, respectively. An increase in the trotting speed can increase the ROM for the joints of the thoracic limbs (Kopec et al. 2018). The dogs in the present study trotted at their natural pace, at a speed that seemed comfortable. Rodrigues (2011) evaluated the gait of six Golden Retriever dogs, affected by muscular dystrophy, during walking. The mean flexion of the articular angle of the carpus was 122.60 ± 11.45 degrees, and was 149.90 ± 19.35 degrees in the extension. The mean flexion for the hip joint was 121.40 ± 11.86 degrees and the mean increased to 150.50 ± 20.17 degrees in the extension. For the knee joint, the mean flexion was 121.20 ± 12.46 degrees and was 146 ± 18.62 degrees for the extension. Compared to our study, a remarkable difference was observed between the values of carpus (extension), hip joint (flexion and extension), and knee (flexion) joints. This difference may be due to the infliction (muscular dystrophy) and/or being of different breeds. In view of the above, more kinematic studies are necessary in dogs, standardising the breeds and conditions that may alter the gait to clarify how the conformation and structure can affect the function.

Nielsen et al. (2003) performed a gait analysis using a two-dimensional and three-dimensional system of thoracic limbs of healthy dogs and stated that there are notable differences between these analyses, such as the angular time-series, because they are totally different technologies. To the best of our knowledge, our study is the first that evaluated the three-dimensional movement of American Pit Bull Terriers.

Various research studies have suggested that the variability in the conformation and size can affect the dogs' kinematics. It is believed that a study including multiple breeds of various sizes leads to a wide variation in the results and limits the ability to detect the expressive characteristics, since the

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pattern of locomotion can change between breeds (Carr et al. 2013; Miqueleto et al. 2013; Kopec et al. 2018). In the present study, the biometric data of the dogs were not measured, but a single breed was standardised, in order to minimise any breed variability.

Therefore, we believe that this study can contribute to establish normality data for gait variables in healthy American Pit Bull Terriers and be useful for the rehabilitation of affected dogs. However, additional studies using other dogs with the same morphological characteristics and the same protocol would be important to determine the viability of the method (Miqueleto et al. 2013).

In conclusion it can be stated, that kinematic studies of locomotion may be useful to characterise the gait of healthy dogs and evaluate the progression of clinical or surgical treatments. In this study, the movement of the pelvic limb is symmetrical in both the trotting and walking phases, which is relevant for the study of dogs with musculoskeletal diseases.

Conflict of interest

The authors declare no conflict of interest.

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