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OZAN GÜNDEMİR

HASAN ALPAK

DİLEK OLĞUN ERDİKMEN

DİDAR AYDIN KAYA

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Evaluation of gait character of Akbaş and Kangal shepherd dogs by using pressure-sensitive walkway

Ozan GÜNDEMİR[1,*], Hasan ALPAK[1], Dilek OLĞUN ERDİKMEN[2], Didar AYDIN KAYA[2]

[1]Department of Anatomy, Faculty of Veterinary Medicine, İstanbul University-Cerrahpaşa, İstanbul, Turkey
[2]Department of Surgery, Faculty of Veterinary Medicine, İstanbul University-Cerrahpaşa, İstanbul, Turkey

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Abstract: In this study, it was aimed to evaluate which walking analysis data may be obtained for Kangal and Akbaş shepherd dogs using a pressure-sensitive walkway (PSW) and which of these data may be used in the fields of veterinary anatomy, orthopedics, and neurology. Center of pressure (COP) analysis results of 46 dogs were examined. Distance type gait parameters of dogs were measured and their foot zone analysis values were recorded. It was observed that the pressure values applied by forelimb steps on the ground were higher compared to the pressure applied by hindlimb steps. The highest peak vertical force (PVF) values were observed in DP3 and DP4 for both forelimbs and hindlimbs. It was determined that the pressure value applied by metapodial pads on the ground were lower compared to digital pads and the PVF values of metapodial pads of the hindlimb were higher than the forelimb metapodial pad values. The correlation between weight and forelimb pressure values was higher than the correlation values between weight and hindlimb pressure values. With the pressure-sensitive walkway system used in the study, COP and foot zone analysis may be performed and distance gait parameters may be measured. It is considered that this system, in which more data may be obtained about the morphometry of walking, is more advantageous with its ease of use compared to other walking analysis systems. It is considered that the studies performed with this system would be a reference in veterinary orthopedic and neurology fields and would contribute to the development of the usage of pressure-sensitive walkway systems for dogs.

Key words: Akbaş shepherd dogs, center of pressure analysis, gait analysis, Kangal shepherd dogs, pressure-sensitive walkway

1. Introduction

Kangal and Akbaş shepherd dogs have been registered as breeds by the Turkish Standards Institution. Both breeds are used as shepherd dogs [1]. These two breeds are included in the class of strongly built dogs among dog breeds worldwide. However,, previous studies have reported that there are differences between these two breeds in terms of both growth characteristics and body characteristics. It has been reported that the Kangal shepherd dog is a more strongly built dog compared to Akbaş shepherd dogs [2].

Motion is defined as the change of location by an object. Motion analysis systems are used in assessing a motion numerically. Walking analysis is one of these systems. By means of the numerical results provided by walking analysis, the anomalies in walking or the disruptions that may not be noticed by veterinary physician are detected [3,4]. One of the most preferred applications of walking analysis is the video recording method. Assessments are made through images in the computer environment and information is obtained about the morphometry of walking. This method is used in the walking analysis of animals [5]. Also, markers are placed on the motion points of animals and data such as their step rate, distance, and number may be obtained [6]. Although this method is practical and cheap, the data obtained are limited and therefore this method is used as an auxiliary for other walking methods. In kinematic analyses, numerical data such as body movements, joint angles, and rates may be obtained. In this method, special cameras and computer systems are also used [7,8]. Also, by special devices placed on plantar, parameters such as the force values applied to the ground and step times may be obtained [9,10]. For the diagnosis of neuromuscular diseases, electromyography may also be used in addition to walking analysis methods. With this method, assessments may be performed by combining the activities and kinetic and kinematic data of muscles during motion [11,12].

Walking plates, another example of walking analysis systems, are used with animals and plantar force values are obtained. Force platform and pressure-sensitive systems may be given as examples of these walking systems. Pressure-sensitive systems can measure the pressure

* Correspondence: ozan_gundemir@hotmail.com

applied by the foot contact area of animals on the ground in Newtons (N). Also, they can reveal the differences in the force values between walking phases by real-time camera records. Based on pressure amounts applied by the foot on the ground, a plantar map is obtained using this system. Also, with this method used for dogs, data have been obtained about step length, stance phase times, and velocity [13,14]. A study was also conducted on cats using pressure plates and the vertical forces applied by cats on the ground after jumping were assessed [15]. These pressure plates are important for objective evaluations during or after treatment [16,17].

Center of pressure (COP) analysis provides information on the orbital change of the force applied to the ground as a result of postural sway. This analysis may be performed using force and pressure platforms [18]. This analysis forms a butterfly-like shape in computer environments, called a cyclogram. The structure and symmetry of this shape provide information about walking characteristics. It may be used to determine pathological walking examples, such as walking asymmetries in particular [19].

In dogs, the third and fourth toes are the longest and the first toe is the shortest one [20]. In the parts of these toes contacting the ground, there are pads, composed of fat and connective tissue, carrying weight. There is a separate digital pad for each toe and also there is a metapodial pad bigger than the digital pads, for each foot, in the end part of metapodial bones. These pads transfer the animal's weight to the ground and form the ground contact pressure [21]. A limited number of studies evaluating the weight or force on these pads have been conducted [21,22]. In a study conducted with lame dogs, the weight changes on these pads were examined and the peak vertical force on especially the metapodial pad in these dogs was low [23].

In this study, it was aimed to evaluate which data may be obtained using a pressure-sensitive walkway system for Kangal and Akbaş shepherd dogs by walking analysis and which of these data may be used in the fields of veterinary anatomy, orthopedics, and neurology.

2. Materials and methods

2.1. Dogs

In the study, 46 healthy shepherd dogs over the age of 2 from the national dog breeding center were used. Before the analysis, the dogs were assessed in terms of pain, crepitation, and effusion and their clinical and orthopedic treatments were completed.

2.2. Pressure-sensitive walkway (PSW)

The Zebris FDM (Full Balance, İstanbul) PSW system was used (Figure 1). This system is composed of a plate having a length of 241 cm, width of 56 cm, and thickness of 2.1 cm; a computer processing these data and showing the values; and a camera recording movement and real-time images. There are 8360 sensors measuring pressure on the plate. The pressure values formed by the contact of the foot to these sensors on the platform are transferred to the computer environment. The platform mechanism was set up in an open area and the dogs walked under the supervision of two specialized veterinary physicians, accompanied by a trained handler on this platform. The dogs walked for two rounds, including an average of 30 steps in each, at normal walking speed. In this recorded walk, first the forelimbs were marked and their values were obtained. Then only the hindlimbs were identified in the system and the hindlimb values were obtained.

2.3. Center of pressure (COP) analysis

First, the COP results of the dogs included in walking analysis were examined. This test demonstrates the weight change of dogs that they perform towards the left and right sides and towards the front and back during walking. With the test results, the nonhomogeneous force balance changes due to the strain caused by a leash or if the dog was afraid of the platform were determined. The result of

Figure 1. Pressure sensitive walkway system.

the sample walking shown in Figure 2A was considered a normal and balanced walking and it was determined in the sample walking shown in Figure 2B that the dog performed nonhomogeneous weight change during walking and the walking analyses of the dogs with such samples were excluded from the assessment. The walking data of only 25 dogs (10 Kangal shepherd dogs, 15 Akbaş shepherd dogs) among the 46 dogs analyzed in accordance with the COP results were assessed (Figure 2).

2.4. Distance type gait (DTG) parameters

During walking, the distance between the left and right step was measured separately for the forelimbs and hindlimbs (step width). The step length passed was measured for forelimbs and hindlimbs. The distance passed by the same leg was measured (stride length) (Figure 3). The cadence and velocity of each animal were obtained during walking. Also, the stance phase and step time were recorded for each leg. The DTG analysis results of steps put out of the platform or on the border of the platform during walking were excluded from the assessment. In case that foot was placed out of the platform, incorrect results were determined especially in step length and stride length analysis values and they were excluded from the study.

2.5. Foot zone analysis (FZA)

Foot zone contacting the ground were examined in 3 regions due to the software characteristics. These regions were determined to be zone 1, the zone where the third digital pad (DP3) and the fourth digital pad (DP4) contact the ground; zone 2, where the second digital pad (DP2) and the fifth digital pad (DP5) contact the ground; and zone 3, where Metapodial pads (MPC: forelimb, MPT: hindlimb) contact the ground. For each region, the maximum force and peak vertical force (PVF) values applied to the ground were determined. The contact time applied to the ground by each foot was recorded. Also, it was determined in what percentage of the contact time the maximum force applied to the ground by foot occurred (Figure 4).

The means and standard deviations of DTG and FZA parameters were obtained separately for Akbaş and Kangal shepherd dogs. The correlation between the weights of animals and the force values applied to the ground by plantar were assessed separately for forelimb and hindlimb.

The study was approved by the Local Ethics Committee of Faculty of Veterinary Medicine, İstanbul University-Cerrahpaşa (approval number: 2019-25836).

3. Results

The dogs walked with 189.56 step/min cadence and 6.19 km/h velocity on the average. The average time of the first step was recorded to be 0.33 s. It was considered appropriate for the gait analysis test results of 15 Akbaş shepherd dogs (4 males, 11 females) with the average weight of 45.54 ± 4 kg and 10 Kangal shepherd dogs (8 males, 2 females) with an average weight of 54.13 ± 8.8 kg to be included in the assessment. The FZA analysis was performed in Kangal shepherd dog and Akbaş shepherd dog and the results related to the pressure values applied on the ground were presented in Table 1 and Table 2. In the maximum force values, it was observed that the DP3 and DP4 values of hindlimb of Akbaş dog were higher compared to the forelimb values of this dog. It was considered that DP2, DP5, and metapodial pad maximum force values were high in forelimb. It was observed in Kangal Shepherd dogs that the forelimb maximum force values were higher for all the regions compared to the values of hindlimb. It was determined that the highest PVF values were of DP3 and DP4 for the same forelimb and hindlimb. It was observed that the application time of the maximum force on the ground was higher in DP3 and DP4 for both forelimbs and hindlimbs. The time maximum force (% of stance phase) values of metapodial pads were shorter compared to the other pads.

The highest PVF values were observed in DP3 and DP4, which were followed by PVF values applied on the ground

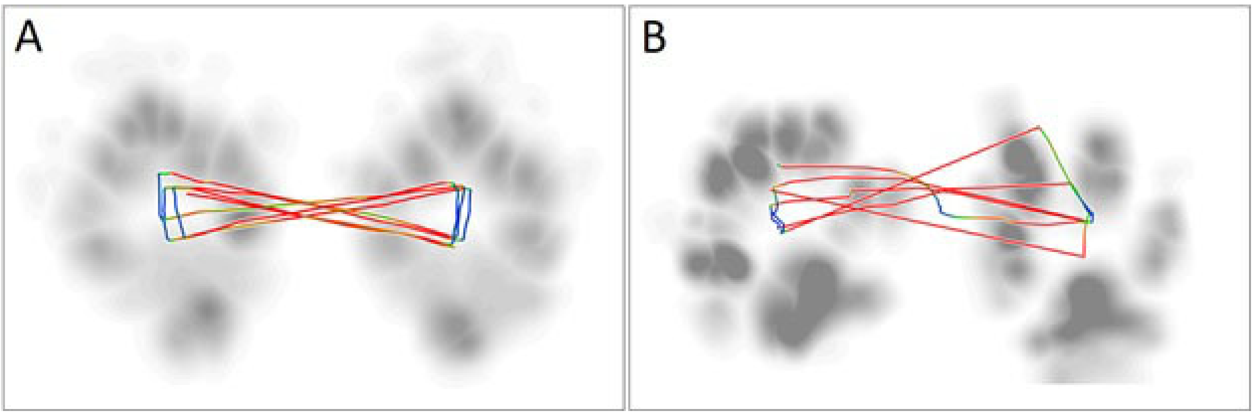

Figure 2. COP analysis, A: Normal, B: Abnormal.

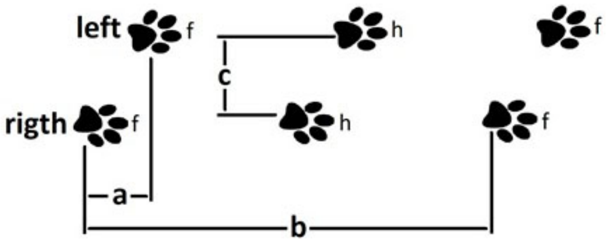

Figure 3. Distance type gait parameters, f: Fore, h: Hind, a: Step length, b: Stride length, c: Step width.

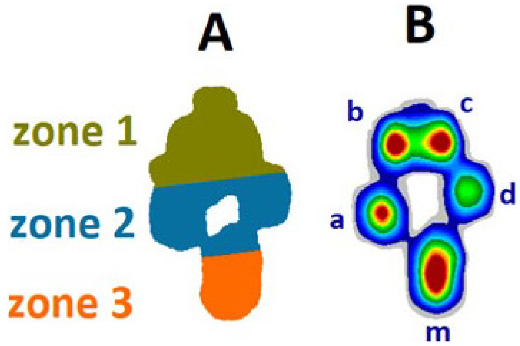

Figure 4. Foot zone area analysis. A: Foot zones, B: Digital pads, a: 1. Digital pad, b: 2. Digital pad c: 3. Digital pad d: 4. Digital pad M: Metapodial pad.

by DP2 and DP5. It was determined that metapodial pads had the lowest PVF values. However, it was observed that MPT had higher PVF values for both breeds compared to MPC. Apart from that, it was determined that the other PVF values were higher in forelimb compared to hindlimb.

It was observed that DP3 and DP4 performed the highest contact time during the stance phase and metapodial pads had the lowest contact time.

The mean values of DTG parameters were obtained for both breeds. It was observed that the step length value was averagely 58 ± 10.54 cm for forelimb and 60.71 ± 12.61 cm for hindlimb in Kangal shepherd dogs and the means of these values for Akbaş shepherd dogs were 56.77 ± 11.32 cm and 54 ± 10.6 cm, respectively. The mean stride length values were recorded as 116.13 ± 23.5 cm in forelimb and 127.17 ± 19.63 cm in hindlimb for Kangal shepherd dogs and 114.92 ± 22.83 cm and 107.33 ± 20.89 cm, respectively for Akbaş shepherd dogs. The mean step width values were 17.33 ± 4.03 cm for forelimb and 18.22 ± 5.85 cm for hindlimb for Kangal shepherd dogs and these values were 11.93 ± 5.12 cm and 19.22 ± 8.03 cm for Akbaş shepherd dogs.

The correlation among weight, maximum force, and PVF values were examined for forelimb and hindlimb (Table 3). Positive correlation was observed in all the results. It was observed that the correlation between weight and forelimb pressure values applied on the ground was higher than the correlation between weight

Table 1. Forelimb and hindlimb foot zone analysis result for Akbaş shepherd dogs.

Measurement	**Zone**		**Akbaş shepherd dogs**							
		N	Forelimb				Hindlimb			
			Mean	SD	Min	Max	Mean	SD	Min	Max
Maximum force (N)	Z1	15	118.00	30.12	72.00	161.00	126.40	30.23	62.00	182.00
	Z2	15	112.00	33.36	40.00	151.00	105.87	38.76	38.00	181.00
	Z3	15	98.13	31.36	44.00	140.00	93.13	33.40	56.00	174.00
PVF (N/cm²)	Z1	15	23.87	4.50	14.00	31.00	22.60	4.52	13.00	30.00
	Z2	15	21.73	4.79	13.00	31.00	20.73	6.42	13.00	32.00
	Z3	15	17.00	5.67	8.00	30.00	20.27	6.04	12.00	34.00
TMF (% of stance time)	Z1	15	59.47	7.57	47.00	70.00	52.27	13.56	23.00	73.00
	Z2	15	47.00	7.30	35.00	59.00	35.73	7.41	26.00	46.00
	Z3	15	35.13	6.91	23.00	47.00	21.80	4.83	14.00	30.00
Contact time (% of stance time)	Z1	15	95.27	2.66	87.00	98.00	94.73	1.62	92.00	98.00
	Z2	15	90.67	2.74	86.00	95.00	86.13	3.98	79.00	92.00
	Z3	15	81.40	5.84	70.00	93.00	76.20	5.27	69.00	86.00

PVF: Peak vertical force, TMF: Time maximum force, SD: Standard deviation, Z1: 3rd and 4th digital pads area, Z2: 2nd and 5th digital pads area, Z3: Metacarpal pad area.

Table 2. Forelimb and hindlimb foot zone analysis result for Kangal shepherd dogs.

Measurement	Zone	N	Kangal shepherd dogs							
			Forelimb				Hindlimb			
			Mean	SD	Min	Max	Mean	SD	Min	Max
Maximum force (N)	Z1	10	155.00	46.20	92.00	245.00	140.00	49.78	83.00	235.00
	Z2	10	128.70	36.68	71.00	195.00	99.80	33.80	59.00	160.00
	Z3	10	115.60	34.24	69.00	170.00	106.90	27.95	67.00	170.00
PVF (N/cm²)	Z1	10	24.40	7.35	16.00	42.00	22.30	9.03	14.00	42.00
	Z2	10	22.20	5.39	15.00	31.00	20.50	6.65	12.00	31.00
	Z3	10	17.50	3.47	12.00	22.00	19.00	3.65	12.00	24.00
TMF (% of stance time)	Z1	10	61.80	6.44	51.00	74.00	50.70	9.43	34.00	66.00
	Z2	10	42.80	7.19	32.00	54.00	37.60	10.47	18.00	51.00
	Z3	10	27.70	6.31	18.00	36.00	25.80	8.74	13.00	40.00
Contact time (% of stance time)	Z1	10	96.10	1.73	92.00	98.00	94.90	2.47	90.00	98.00
	Z2	10	92.10	2.33	88.00	96.00	88.90	4.09	80.00	94.00
	Z3	10	81.20	7.13	63.00	89.00	76.40	8.54	63.00	86.00

PVF: Peak vertical force, TMF: Time maximum force, SD: Standard deviation, Z1: 3rd and 4th digital pads area, Z2: 2nd and 5th digital pads area, Z3: Metacarpal pad area.

Table 3. Correlation between pressure and weight values for forelimb and hindlimb for all dogs.

			MF (Newton)			PVF (Newton/cm²)			
		Weight	Z1	Z2	Z3	Z1	Z2	Z3	
	Weight	1	.319	.202	.350	.445*	.329	.049	Hindlimb
MF (Newton)	Z1	.612**	1	.696**	.394	.679**	.651**	.195	
	Z2	.467*	.793**	1	.409*	.644**	.750**	.376	
	Z3	.456*	.741**	.708**	1	.458*	.561**	.572**	
PVF (Newton/cm²)	Z1	.539**	.663**	.531**	.578**	1	.715**	.339	
	Z2	.447*	.476*	.602**	.551**	.729**	1	.760**	
	Z3	.427*	.441*	.584**	.595**	.580**	.772**	1	
		Forelimb							

MF: Maximum force, PVF: Peak vertical force, Z1: 3rd and 4th digital pads area, Z2: 2nd and 5th digital pads area, Z3: Metacarpal pad area.
*: Correlation is significant at the 0.05 level
**: Correlation is significant at the 0.01 level

and hindlimb pressure values applied on the ground. The highest correlation was determined in maximum force values between zone 1 (DP3 and DP4) and zone 2 (DP2 and DP5) for forelimb. The lowest correlation values were determined between weight and hindlimb MPT values. In the correlation test performed between velocity and stance phase, negative correlation was observed.

4. Discussion

In the study, the pressure values between metapodial pads and digital pads of the limb contacting the ground were examined and the differences were presented. In this study, examining the foot zone of Akbaş and Kangal shepherd dogs in 3 regions, it was determined that DP3 and DP4 had the highest PVF for forelimb and hindlimb, which was followed by DP2 and DP5. For metapodia, it was observed that MPT PVF values were higher for both Akbaş and Kangal shepherd dogs compared to MPC values. It was reported in the measurements obtained in healthy pitbulls that MPC had the highest PVF in forelimbs and DP3 and DP4 had the highest PVF in hindlimbs [23]. It was reported that for greyhound breed dogs, DP3, DP4, and DP5 had the highest PVF in forelimb and DP3, DP4, and MPT had the highest PVF in hindlimb and for Labrador Retriever dogs MPC had the highest PVF values in forelimb and DP4 has the highest PVF values in hindlimb [22]. In the study conducted on German shepherd dogs, it was stated that DP3, DP4, and DP5 had high PVF values for forelimb and DP3 and DP4 had high PVF values for hindlimb [24]. It was reported for English pointer dogs that DP3 and DP5 had the highest pressure and DP2 and DP4 had the lowest pressure for forelimb and hindlimb [21]. In all the studies, it was observed that the forelimb PVF values were high as in this study. However, the fact that the highest PVF values obtained as a result of the studies conducted in healthy animals were observed in different digital pads. supports the thesis stating that there may be a difference in stepping between breeds. In this study, it was observed that the highest PVF value rank was the same between Kangal and Akbaş shepherd dogs although there was a difference with the other breeds.

In gait analyses, the stance phase times and velocity values are also obtained. Also, stance phase time is directly related to velocity. When velocity increases, stance phase time decreases [25]. As each walking sample occurs at an equal rate, the presence of a difference between stance phase times is possible. In such cases, to minimize failure, it is considered that the information on percentage of stance phase in a walking cycle will be more correct [26]. Also, it is considered that the comparison of stance phase values of the problematic leg of the sample dog with values of the other legs of the dog that are considered to be healthy instead of the reference values obtained previously will be more appropriate in terms of orthopedic assessment for stance phase values in case of lameness [27–29].

There are studies examining the relationship between gait analysis values in healthy animals using the body sizes [9,30]. Although the body characteristics are different as in the study, the value data of the force on walking in forelimb were observed to be higher compared to hindlimbs [13,24]. Apart from this, the fact that stride length, mean total pressure index, and peak vertical force increased with increasing body morphometric values supports the literature data [31].

COP analysis was used in the study to determine the negative effects of leash or environmental factors, which may affect normal walking order of healthy dogs, on walking. The samples having a nonhomogeneous weight distribution were excluded from assessment. It is considered that this system will be useful in the studies in which normal walking reference data will be obtained. This system was used before in dogs with spinal cord injury [16,32]. In the studies, the differences in walking dynamics between healthy dogs and dogs with spinal cord injury were determined based on the results of COP analysis. It is considered that further studies should be conducted to obtain reference information with COP analysis method, with which we may obtain especially the numerical data of the weight changes in walking due to neurological damage and the technique should be improved.

One of the most significant differences of pressure sensitive walkway systems from the other walking systems is that they provide more data and they have ease of use. Also, it provides advantage against force plates with limb symmetry data property [33]. Information of the symmetry of walking was obtained by means of COP test of PSW system used in the study. With the results of this test, the samples in which leash or the other external factors affecting the walking results of dogs were determined because it was reported in the previous studies that especially the use of leash was effective on pressure values [34,35].

PSW system has been used in both healthy [36,25] and lame [16,17,37] dogs and the reference data have been obtained. Using especially PVF data, the data of the dogs with orthopedic problems have been compared. With PSW system, the pressure data applied by each foot on the ground may be assessed separately. These numerical data are considered to help physicians during diagnosis. Also, with 3-dimensional plantar pressure map, physicians have the advantage of performing faster interpretations. The reference data are considered to be useful in the diagnosis of neurological diseases causing balance disorder in walking by using COP test. It is considered using DTG parameters that walking morphometric characteristics between animals may be revealed. In this respect, it is considered that the studies in which reference data of the anatomic characteristics of walking would be obtained will increase and also reference data would contribute to the improvement of the usage area of PSW system in dogs.

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