FIRST EVIDENCE OF THE USE OF KINETIC GAIT ANALYSIS AS A CLINICAL TOOL FOR EARLY DETECTION OF CHRONIC FOOT DISEASE IN AN INDIAN RHINO (RHINOCEROS UNICORNIS)

Pfistermüller R.[1*], C. Walzer[2] & T. Licka[3]

[1] Vienna Zoo, Maxingstr. 13b, A-1130 Vienna r.pfistermueller@zoovienna.at
[2] University of Veterinary Medicine, Research Institute of Wildlife Ecology, Savoyenstr. 1, A-1160 Vienna
[3] University of Veterinary Medicine, Clinic for Orthopaedics in Ungulates, Veterinärplatz 1, A-1210 Vienna

Abstract

Avoidance, control and treatment of Chronic foot disease (CFD) is the major health issue in many captive Indian Rhinos [1]. CFD is characterized by lesions between the central toe and the pad, that frequently become infected and are difficult to treat [2]. Deviations from a certain gait pattern can reveal clinical problems within the muscoskeletal system in horses before signs of pain are exhibited by the animal. Therefore gait analysis is already used as a clinical tool in this species [3].

In this case study kinetic gait analysis detected first signs of possible beginning CFD, even before the animal showed any signs of pain. Kinetic gait analysis was performed on a female Indian rhino, wild born in 2003 in Chitwan National Park and transferred to the Zoo Vienna, Austria, in March of 2006 using a pressure plate system (Tekscan Walkway 4 with research software, Savecomp Megascan GmbH). Measurements were taken between June of 2006 and spring of 2011.

Twenty-three parameters were examined and compared to detect differences between left and hind feet. Most prevalent was a difference in the trajectory of the center of force (COF) between left and right hind foot in February of 2010. The trajectory of the COF in the animal's right hind foot increasingly differed from the other three feet. To exclude pain as a factor for this change a 3-day therapy with an NSAID (Phenylbutazon) was administered, which acts anti-inflammatory and analgesic. Subsequent data collection did not reveal any difference in COF trajectory. No difference in stance duration or vertical force could be detected between left and right hind feet.
Data collection in spring of 2011 exhibited an area of increased pressure on the anterior part of the foot pad in the hind right foot of the female animal, according to von Houwald [2] an area of minor resistance. In addition, the center of force (COF) was located directly on the area of increased pressure meaning that shear forces were high. Visual control of the sole and pad did not show any signs of cracks or swelling.

It is suggested that a change in COF trajectory in one foot of an Indian rhino is an innovative, non-invasive, objective, and easy to detect sign of developing CFD. In addition, areas on the foot pad with increased pressure can be easily detected and assessed before they are visible to the human eye.

Introduction

Avoidance, control and treatment of Chronic foot disease (CFD) is the major health issue in many captive Indian Rhinos [1]. CFD is characterized by lesions between the central toe and the pad, that frequently become infected and are difficult to treat [2]. It has first been reported by Strauss and Seidel [4]. CFD is considered husbandry related, arising out of horn abrasion on hard surfaces and overfeeding [1, 5, 6]. Von Houwald and Flach [7] carried out a survey in American and European institutions which came to the conclusion that 25% of all captive Indian rhinoceros exhibit signs of CFD and showed that males are more commonly affected than females with the problems starting to occur most commonly between age 7 and 11. Von Houwald (2001) reported that all breeding bulls she investigated in European institutions were affected by CFD as well as 50% of adult females.

To prevent CFD in young animals husbandry guidelines concerning enclosure design and recommendations for feeding are very strict. Recommended bottom substrate in the outdoor enclosure consists of alluvial sand, clay, wood chips or mulch. Indoor floors should be non-abrasive, non-slippery and easy to clean. Recommended are floor coverings, like Relatex or Horsefriends, but hoofed stock rubber mats work as well. Newly built facilities should install rubber coating next to pools and wallows, as well as at exits. The remaining areas should be covered by a 60 – 100 centimeter deep layer of bark or wood chips. Stable tiles or concrete floor should be avoided due to abrasive surfaces. Access to a scale is highly recommended to watch food intake. Adult rhinos should approximately take in 1% of their body mass per day, consisting of a balanced, good quality diet fed in small portions throughout the day, including hay and straw, formulated pellets, cavalino (pressed hay), fruits, vegetables, grass, branches and leaves. Alfalfa pellets should be limited to 20% of entire pellet intake. Pellets should not exceed 33% of entire daily diet. Fresh browse needs to be provided as often as possible at different spots throughout the enclosure, avoiding plants known to be toxic to horses. [1]

If feet are at all controlled for CFD this is carried out visually by keepers and veterinarians during regular training sessions or when animals are lying down to rest and soles are visible.

Treatment of CFD depends on the severity. Minor cracks are treated with a paste of lanolin, fish liveroil, chlorhexidin (5%) and sometimes formol at CERZA (Huyghe 2008, personal communication). In severe cases surgical interventions involve regular debridement, aggressive trimming and paring of overgrown hoof tissue and the periodical application of collagen to stimulate granulation [8].

An innovative and non-invasive way of detecting early signs of Chronic Foot Disease is the use of kinetic gait analysis. Deviations from a certain gait pattern do reveal clinical problems within the muscoskeletal system in horses before signs of pain are exhibited by the animal. Therefore gait analysis is already used as a clinical tool in this species [3].

Method

The female Indian Rhino Sundari from Vienna Zoo was wild born in Chitwan National Park in 2003. She was found orphaned and was handraised at the wildlife orphanage in the park. Due to her closeness to humans she was not able to be reintroduced to the wild again and therefore was transferred to Vienna Zoo at the age of approximately three years.

Kinetic gait analysis war performed with a pressure plate system (Tekscan Walkway 4, Savecomp Megascan GmbH), consisting of four embedded 7100 Sensors, á 45 cm x 50 cm, providing an overall measuring area of 90 cm x 100 cm, with four pairs of dual handles. Spatial resolution was 0.64 mm x 0.64 mm, measuring frequency 39 Hz. The walkway was embedded into an aluminium frame measuring 120 cm x 110 cm x 7 cm (width x length x height) and could be levelled with a set of screwed in feet. In addition, two aluminium ramps could be attached to the front and the back of 120 cm x 100 cm (width x length). The entire measurement setup was covered with a 1 cm thick custom cut rubber mat and was placed in the walkway at the rhino house. A portable device with two four port PCI Super Receivers was the connection between the pressure plate, a linked video camera for reference data, and a notebook with a I-Scan research software.

Data were collected weekly or biweekly between June 2006 and June 2007 and sessions were embedded into the daily routine. For analyses the data of the first year were grouped into three to ensure that sample size was large enough and resolution was still good. Additional sampling with an aimed sample size of N=10 were performed after that in fall of 2008- 2010 and in spring of 2009-2011.

For data collection the animal was asked to walk as straight as possible with no stops and at normal speed across the pressure plate. Measurements were regarded as valid when the gait appeared smooth and when at least one foot stepped on the plate entirely. All together 54 data collection days and 351 data sets in Sundari were carried out.

Table 1: Sample size of each foot throughout data collection periods

	Front right foot	**Front left foot**	**Hind right foot**	**Hind left foot**
Female Sundari				
June – Sep. 06	33	22	29	22
Oct. 06 – Jan. 07	18	21	20	20
Feb. – May 07	13	25	10	22
Aug./Sept. 08	9	7	7	9
March 09	12	15	12	14
Sept. 09	13	13	15	11
Feb. 2010	12	13	11	11
April I 2010	19	10	18	8
April II 2010	10	15	11	15
Sept. 2010	14	9	14	10
March 2011	13	10	13	10

When differences between left and right foot started to arise, a therapy for potential pain, NSAID (Phenylbutazon), was administered in a dose of 1,5g twice a day for the course of 3 days between two additional data collection sessions on April 8 (April-I) and April 19 (April-II), 2010.

23 parameters were monitored compared between left and right foot. Parameter included stance duration (s), Impuls (N*s), Mean force (N), Overall force (N), Maximum force (N), maximum and minimum forces occurring in hind feet during contact landing/stance support (P1) and push

off/break over (P2) phases, their occurrence within the stance duration (%), the COF trajectory, the medio-lateral and dorso-palmar/plantar position of the COF, foot length and width (cm), the length of the central toe (cm), Peak contact area (cm^2), Maximum contact area (cm^2), the occurrence of the maximum contact area within stance duration (%), Front and hind foot overlap, and the presence of a central toe concavity.

Data were analysed descriptively.

Results

The COF trajectory displays the movement of the center of force for the duration of a recording. The COF trajectory within the foot print was then assessed in categories: (1) running from lateral toe across pad to central toe, (2) running from the pad to the central toe, (3) unclear and (4) u-shaped, running from the central toe to the pad and back to the central toe (Figure 1). Most obvious was the difference of COF trajectory in the hind right foot throughout data collection periods starting in fall of 2008 (Table 2; Figure 2). Starting in fall of 2008 a higher percentage of ‘pad-central toe’ trajectories can be seen compared to the other feet. Apart from less than 3% u-shape measurement during the first data collection period in the hind left foot, u-shape of the COF trajectory starts to arise in September of 2009. Since differences of COF trajectories persisted through February of 2010, it was decided that an additional data collection session was run on April 8, 2010 (April-I), followed by a 3- day therapy with NSAID (Phenylbutazon) on April 16-18, 2010. 1,5g of the anti-inflammatory and analgesic agent were administered twice a day throughout the therapy. Another data collection session was carried out on April 19, 2010 (April-II). COF trajectories remained similar after NSAID therapy to before. U-shaped COF trajectories remained at about 40% of all recorded data in the right rind foot, pad-central toe COF trajectories even slightly increased. COF trajectories in the hind left foot almost exclusively ran from the lateral toe to the pad to the central toe (Figure 2; Table 2). Stance duration was generally longer during April data collection sessions compared to other sessions. However in both data collection sessions before and after administration of NSAID stance duration was equal between left and right hind foot (1 second before and 1,1 seconds after NSAID administration (Table 3). Maximum force in the hind feet was also equal between left and right before NSAID administration and after. In both data collection session the difference was around 20 N. (Table 3) In March of 2011 more than half of all COF trajectories were u-shaped and almost none started laterally (Figure 2; Table 2). Visual assessment of the pressure distributions on the recordings of all footprints exhibited an area of increased pressure on the anterior part of the foot pad in the hind right foot of the animal in March of 2011 (Figure 3). In addition, the center of force (COF) was located directly on the area of increased pressure. Stance duration and maximum force were again equal between left and right hind feet during this data collection session (Table 3). Visual control of the actual sole and pad of the animal did not show any signs of cracks or swelling.

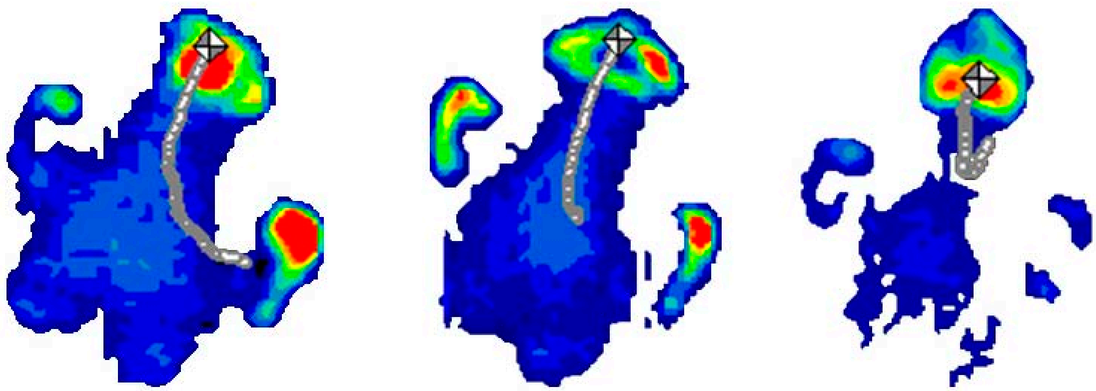

Figure 1: Different categories of COF trajectories in sample pressure recordings. The grey line indicates the COF trajectory. Categories from left to right: lateral toe – pad – central toe, pad – central toe, u-shape

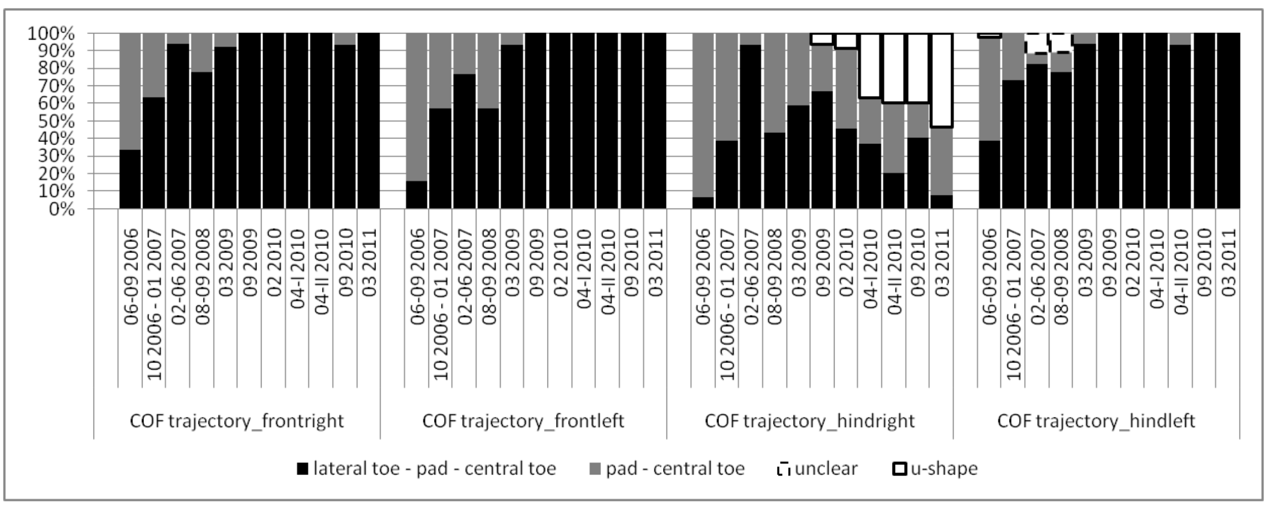

Figure 2: Relative occurrence of different categories of COF trajectories in all four feet.

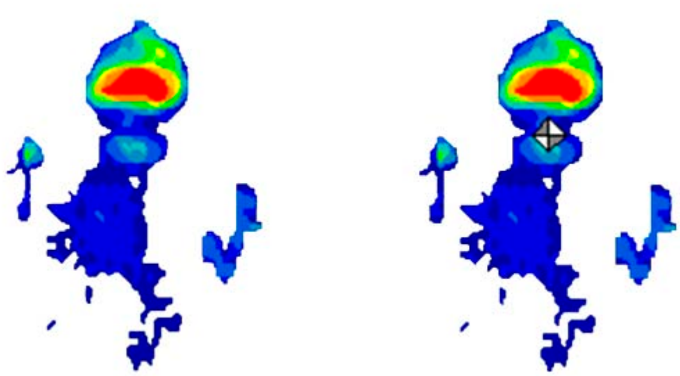

Figure 3: Pressure recording of hind right foot, March 2011. Square in the right picture indicated the COF.

Table 2: Relative occurrence of different categories of COF trajectories in hind feet.

	lateral toe - pad - central toe		pad - central toe		unclear		u-shape	
	COF trajectory hindright	COF trajectory hindleft	COF trajectory hindright	COF trajectory hindleft	COF trajectory hindright	COF trajectory hindleft	COF trajectory hindright	COF trajectory hindleft
06-09 2006	6,45%	38,46%	93,55%	58,97%				2,56%
10 2006 - 01 2007	38,46%	72,73%	61,54%	27,27%				
02-06 2007	93,33%	82,35%	6,67%	5,88%		11,76%		
08-09 2008	42,86%	77,78%	57,14%	11,11%		11,11%		
03 2009	58,33%	93,75%	41,67%	6,25%				
09 2009	66,67%	100,00%	26,67%				6,67%	
02 2010	45,45%	100,00%	45,45%				9,09%	
04-I 2010	36,84%	100,00%	26,32%				36,84%	
04-II 2010	20,00%	92,86%	40,00%	7,14%			40,00%	
09 2010	40,00%	100,00%	20,00%				40,00%	
03 2011	7,69%	100,00%	38,46%				53,85%	

Table 3: Averaged values of gait parameters for timegroups from fall 2008 until spring 2011 (MM.YYYY)

	08-09 2008	03 2009	09 2009	02 2010	04-I 2010	04-II 2011	09 2010	03 2011
Stance duration (s): frontright	1,20 ± 0,19	1,13 ± 0,17	1,15 ± 0,23	1,02 ± 0,08	1,17 ± 0,12	1,29 ± 0,05	1,06 ± 0,08	1,11 ± 0,12
Stance duration (s): frontleft	1,18 ± 0,20	1,11 ± 0,17	1,32 ± 0,23	1,11 ± 0,13	1,18 ± 0,08	1,31 ± 0,13	1,06 ± 0,06	1,08 ± 0,06
Stance duration (s): hindright	1,12 ± 0,20	1,02 ± 0,13	1,01 ± 0,14	0,93 ± 0,07	1,02 ± 0,13	1,12 ± 0,06	0,93 ± 0,07	0,99 ± 0,06
Stance duration (s): hindleft	1,06 ± 0,16	0,94 ± 0,08	1,08 ± 0,18	0,97 ± 0,11	1,03 ± 0,07	1,10 ± 0,11	0,92 ± 0,04	0,98 ± 0,10
Maximum force (N): frontright	3319,98 ± 152,38	2678,50 ± 416,06	3335,81 ± 394,72	2564,25 ± 274,64	2608,57 ± 314,92	2672,11 ± 373,27	3357,34 ± 364,81	3074,50 ± 169,93
Maximum force (N): frontleft	3375,65 ± 578,61	2738,97 ± 352,74	3233,13 ± 422,46	2481,91 ± 216,53	2725,30 ± 184,56	2601,41 ± 350,77	3248,07 ± 330,29	3065,09 ± 201,37
Maximum force (N): hindright	2029,97 ± 219,53	1521,53 ± 155,31	1725,52 ± 274,15	1493,15 ± 108,78	1487,09 ± 133,17	1444,72 ± 185,68	1843,20 ± 187,89	1832,60 ± 138,78
Maximum force (N): hindleft	2084,67 ± 293,87	1420,54 ± 189,26	1753,85 ± 224,70	1355,37 ± 168,16	1463,59 ± 249,94	1466,27 ± 229,12	1770,52 ± 210,98	1784,15 ± 117,58

Discussion

Even though COF trajectories during the first year of data collection varied and showed quite a high proportion of a pad-central toe motion, trajectories in all four feet were quite similar (Figure 2; Table 2). These increased pad landings at a younger age are correlated to the normal increased carpal conformation in calves, which can also be observed at neonatal foals, but might persist longer in Indian rhinos than known from horses, in which it normally disappears at 8-10 months of age [9]. According to Dinerstein [10] Indian rhinos are still considered calves until the age of 4 years, an age that the animal reached in fall of 2007 after the first year of data collection.

Over all the largest percentage of COF trajectories ran from the lateral toe across the pad to the central toe (Figure 2). Therefore this can be considered the normal condition for this animal when it was older than 4 years. In horses the preferred way of landing is also lateral in both front and

hind feet [11]. Front feet in cattle exhibit an even distribution of the load between lateral and medial toe, but again on hind feet at heel strike most pressure was seen on the lateral claw [12].
To a certain degree individual differences between left and right are normal. In clinically sound horses at the trot, left-to-right asymmetry of force, temporal and spatial parameters can be seen between 1,8% and 6,8% [13]. The difference in COF trajectories between the right hind foot and all other four feet is quite conspicuous and since the condition developed over time it needed to be assessed if the animal was in pain. The NSAID therapy did not result in a change in the COF trajectory. However, it might be possible that the dose was not high enough or the therapy was not administered for long enough for the animal to show an analgesic effect. It is known that tetrapods try to relief pain in a foot by a shortened stance duration and a lower vertical force [14, 15]. The assessment of stance duration and maximum vertical force between left and right hind feet did not show any difference (Table 3). Therefore it has to be concluded that the animal was not in pain.

Nevertheless, recordings in spring of 2011 revealed for the first time an area of increased pressure on the anterior part of the footpad (Figure 3), the area von Houwald [2] determined an area of minor resistance. In addition, the center of force (COF) was located directly on the area of increased pressure meaning that shear forces were high but equal stance duration and maximum force between left and right hind again suggested that the animal was not trying to relief pain in any foot. Visual control of the actual sole and pad of the animal did not show any signs of minor cracks or swelling. The area of increased pressure on the anterior footpad might already be a first sign of an increased strain due to large shear forces, which is also suggested by the fact that the center of force is exactly located in this area. It might easily be possible that CFD is the next logical step to follow if husbandry conditions are not changed.

The fact that through kinetic gait analysis a change in the COF trajectory was already detected two years prior to a first sign of increased pressure on the anterior footpad, which was still not visible to the human eye or caused any pain in the animal, suggests that kinetic gait analysis is an innovative, non-invasive and objective method to detect future possible foot problems in Indian rhinos long before they become a problem.

References

1. Guldenschuh, G., and F. Von Houwald. 2002. Husbandry Manual for the Greater One-Horned or Indian Rhinoceros *Rhinoceros unicornis* Linné, 1758. Basel Zoo.
2. von Houwald, F. 2001. Foot problems in Indian Rhinoceroses (*Rhinoceros unicornis*) in zoological gardens: Macroscopic and microscopic anatomy, pathology and evaluation of the causes. Universität Zürich, Zürich.
3. Peham, C. 1999. Methoden und klinische Anwendungen der Bewegungsanalyse des Pfe des unter besonderer Berücksichtigung der Lahmheit. University of Veterinary Medicine Vienna, Vienna.
4. Strauss, G., and B. Seidel. 1982. Pododermatitis purulenta beim Panzernashorn (*Rhinoceros unicornis*) - ein Fallbericht. Verhandlungsbericht des Internationalen Symposiums uber die Erkrankungen der Zootiere 24: 177-181.
5. Von Houwald, F. 2001. Foot problems in Indian Rhinoceroses (*Rhinoceros unicornis*) in zoological gardens : Macroscopic and microscopic anatomy, pathology and evaluation of the causes. . Dissertation, Universität Zürich, Zürich.

6. von Houwald, F. 2002. An Overview of Pathological Alterations of Hooves and Soles of Captive Indian Rhinos (*Rhinoceros unicornis*) and a Comparison of Anatomical Foot Structures of Captive and Wild Indian Rhinoceroses. In. Schwammer, H. M., Foose, T. J., Fouraker, M., and Olson, D., (eds.). A research update on elephants and rhinos: proceedings of the International
7. Elephant and Rhino Research Symposium, Vienna, June 7-11, 2001, ed. Schüling, Münster. Pp.331-332.
8. Von Houwald, F., and E. Flach. 1998. Prevalence of chronic foot disease in captive greater one horned-rhinoceros (*Rhinoceros unicornis*). Second Scientific Meeting. European Association of Zoo- and Wildlife Veterinarians (EAZWV), Chester, United Kingdom.
9. Atkinson, M. W., R. A. Gandolf, B. Hull, and E. Blumer. 2002. Long-Term Medical and Surgical Management of Chronic Pododermatitis in an Greater One-Horned Rhinoceros. In. Schwammer, H. M., Foose, T. J., Fouraker, M., and Olson, D., (eds.). International Elephant and Rhino Research Symposium, ed. Münster:Schüling, Vienna. Pp. 159-163.
10. Trumble, T. N. 2005. Orthopedic Disorders in Neonatal Foals. The Veterinary clinics of North America. Equine practice 21: 357-385.
11. Dinerstein, E. 2003. The Return of the Unicorns: Natural History and Conservation of the Greater-One Horned Rhinoceros. Columbia University Press.
12. van Heel, M. C. V., A. Barneveld, P. R. van Weeren, and W. Back. 2004. Dynamic pressure measurements for the detailed study of hoof balance: the effect of trimming. Equine Veterinary Journal 36: 778-782.
13. van der Tol, P. P. J., J. H. M. Metz, E. N. Noordhuizen-Stassen, W. Back, C. R. Braam, and W. A. Weijs. 2003. The Vertical Ground Reaction Force and the Pressure Distribution on the Claws of Dairy Cows While Walking on a Flat Substrate. J. Dairy Sci. 86: 2875-2883.
14. Weishaupt, M. A. 2004. Compensatory mechanisms of weightbearing lameness in horses - a novel approach by measuring vertical ground reaction forces on an instrumented treadmill. PhD Dissertation, Vetsuisse-Faculty University of Zürich, Zürich.
15. Judy, C. E., L. D. Galuppo, J. R. Snyder, and N. H. Willits. 2001. Evaluation of an in-shoe pressure measurement system in horses. Am J Vet Res 62: 23-28.
16. Akikazu, I., L. B. Alicia, and J. R.-S. Päivi. 2005. Association between subjective lameness grade and kinetic gait parameters in horses with experimentally induced forelimb lameness. Am J Vet Res 66: 1805-1815.