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Lameness detection using an accelerometric device

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Summary

In order to test the efficiency of a gait analysis system in veterinary practice conditions, the locomotion of the horses presented for lameness in an equine veterinary clinic were systematically explored using an accelerometric device. The purpose of this study was to compare for each case the diagnosis established by an equine practitioner with the results of a locomotor test. Twenty six lame horses were examined according to a standardized clinical protocol. Six control horses were tested for comparison with the 26 lame horses. The stride frequency, symmetry, regularity, and side of maximum loading were determined at walk and trot. It was concluded that the accelerometric device could be useful in veterinary pratice for quantifying the degree of a lameness. The locomotor test performed at walk was able to detect in most of the cases subtle lameness and the side of the lame limb could be determined.

Keywords: Horse, lameness, biomechanics, gait symmetry, accelerometry

Erkennung von Lahmheiten mittels Beschleunigungsmessung

Um ein System zur Ganganalyse unter den Bedingungen einer tierärztlichen Praxis zu testen, wurde die Fortbewegung von Pferden, die wegen Lahmheit in einer Pferdeklinik vorgestellt wurden, systematisch unter Zuhilfenahme eines Beschleunigungsmessers untersucht. Die Diagnose eines Pferdepraktikers wurde mit den Ergebnissen des Fortbewegungs-Tests verglichen.
26 Pferde mit Lahmheiten wurden nach einem standardisierten klinischen Protokoll untersucht, zum Vergleich wurden 6 gesunde Pferde der gleichen Prozedur unterzogen.
Mit dem am Sternum plazierten Beschleunigungsmesser wurden Beschleunigungen entlang der dorsoventralen und lateralen Achse des Pferdes erfaßt. Die Parameter Schrittfrequenz, Symmetrie, Regelmäßigkeit und Seite der maximalen Belastung wurden im Schritt und Trab erfaßt.
Es zeigte sich, daß der Beschleunigungsmesser hilfreich ist bei der Quantifizierung des Grades einer Lahmheit. Der Fortbewegungs-Test im Schritt genügte in den meisten Fällen, um leichte Lahmheiten zu erkennen und die Seite der Lahmheit zu erfassen.

Schlüsselwörter: Pferd, Lahmheit, Biomechanik, Gangsymmetrie, Beschleunigungsmessung

Introduction

Lameness is by far the most important factor causing decreased performance and use of horses (*Jeffcott* et al. 1982, *Lindholm* 1987). Hence, equine practitioners are often confronted with difficulties of lameness examination and diagnosis. Many technologies have been proposed to identify lesions causing lameness. Force plates were used to assess quantitatively the degree of lameness (*Morris* and *Seeherman* 1987, *Merkens* and *Schamhardt* 1988). Two and 3-dimensional motion analysis systems were employed to study the kinematics of various types of lameness (*Clayton* 1986, *Back* et al. 1993, *Buchner* et al. 1993, *Deuel* et al. 1995). However, all these methods require a laboratory environment and the analyses are too lengthy to be practical. With the improvement of the accelerometric transducers and signal conditioning it is now possible to provide the practitioner with some locomotor analysis systems which are less sophisticated, but useful for quantifying the degree of lameness.
An accelerometric device was specifically designed to measure stride parameters in field environments with the aim of investigating the relationships between locomotion and performance in races (*Barrey* et al. 1995) or equestrian sports (*Barrey* and *Galloux* 1996) for selection purposes. However, it was shown that this system was able to detect gait asymmetries of experimentally induced lameness (*Barrey* et al. 1994). In order to test the efficiency of the system in veterinary practice conditions, the locomotion of horses presented for lameness in an equine veterinary clinic were systematically explored using this accelerometric device. The purpose of this study was to compare for each case the diagnosis established by an equine practitioner with the results of a locomotor test.

Materials and methods

Horses and clinical examination
A total of 32 horses were tested. Twenty six of them were presented for lameness and examined according to a standardized protocol established by Desbrosse, an equine practitioner specialized in locomotion disorders (*Courouсé* et al. 1995). Radiography and/or ultrasonography were used to identify the injury. All types and degrees of lameness were selected in order to test the sensitivity of the accelerometric device. In each case, the affected limb(s) and location(s) of injuries were noticed.

Tab. 1: Horse characteristics and results of the locomotor tests.

N°	Breed	Age	Sex	Diagnosis: order – location – injury	Grade	Walking Test Sym	 Reg	 Lat	 SF	Trotting Test Sym	 Reg	 Lat	 SF
5	SF	8	F	1-RF – Carpus fracture 2-LH – bone spavin 3 days after arthodesis 3-RH – Tenosynovitis 4-Overlapping thoracic dorsal spinous process	3	25	125	L>R	0.73	–	–	L>R	–
6	SF	9	F	1-RF – DJD coffin joint 2-LF – Sidebones of distal phalanx 3-RF+LF – Navicular disease	3	80	154	–	0.88	88	177	–	1.66
7	SF	10	F	1-LF – Navicular disease with adhesions between the navicular bone and deep digital flexor tendon	3	85	136	R>L	0.98	64	141	R>L	1.56
11	TF	7	G	1-RF – Articular fracture of elbow joint – 6 weeks after surgery	3	91	169	–	0.98	–	–	–	–
9	AA	7	F	1-RF-Hoof abcess	2	80	153	L>R	0.78	94	175	L>R	1.61
8	TF	14	G	1-RF – Shoulder joint DJD 2-RH – partial upward fixation of the patella and bone spavin	2	85	177	L>R	0.88	99	190	L>R	1.46
1	S	8	G	1-LF – Tendinitis of the brachialis muscle	2	87	165	R>L	0.88	97	197	R>L	1.46
4	TF	4	F	1-LH – Exostosis reduction surgery 2-Left lumbar pain 3-LF+RH – ringbone	2	87	117	–	0.83	97	194	–	1.42
2	Pa Fi	6	F	1-Right subluxation of sacroiliac joint 2-RH – Fetlock joint 3-RH – Hock joint	1	66	191	L>R	0.93	92	191	L>R	1.81 Tölt
14	S	14	G	1-RF – Cyst of the navicular bone after local anesthesia	1	66	166	L>R	0.78	99	194	L>R	1.41
20	TF	4	M	1-LF – Tendinitis suspensory ligament 2-RF – Old subluxation of the coffin joint	1	79	145	R>L	1.07	100	177	R>L	1.51
18	SF	13	G	1-RH – DJD coffin joint – 5 months after surgery 2-Overlapping thoracic dorsal spinous process	1	81	153	R>L*	0.98	98	151	R>L*	1.56
3	PaPe	4	F	1-RH and LH partial upward fixation of the patella	1	86	186	R>L*	0.78	98	186	R>L*	1.61 Tölt
26	S	18	G	LF-RF – Upright pastern – Tenosynovitis	1	86	178	–	0.86	96	196	–	1.48
12	TF	3	F	1-LF – Sidebone distal phalanx 2-Lumbar pain	1	90	190	–	1.07	98	198	–	1.56
13	TF	5	M	1-RF – Fracture of the palmar process of the distal phalanx	1	90	190	–	0.92	96	193	–	1.80
16	TF	4	F	1-RF – Osteitis – 6 months after surgery	1	90	175	L>R	1.07	98	176	L>R	1.76
21	TF	3	G	1-RF+RH 2-Overlapping thoracic dorsal spinous process	1	90	168	L>R	0.98	98	188	L>R	1.42
27	SF	13	G	RF+LF – Navicular disease	1	90	184	–	0.88	99	193	–	1.51
23	SF	7	F	1-RF-DJD Fetlock joint	1	93	186	L>R	1.03	98	192	L>R	1.51

Tab. 1: Continued

N°	Breed	Age	Sex	Diagnosis: order – location – injury	Grade	Walking Test				Trotting Test			
						Sym	Reg	Lat	SF	Sym	Reg	Lat	SF
32	SF	20	G	1-RF – Fetlock	1	93	191	–	0.88	97	197	–	1.35
10	TF	6	G	1-LF-Healing of suspensory ligament tendinitis 2-RH-LH Old osteochondrosis of the tarsus joint	1	94	182	–	0.93	100	185	–	1.51
22	SF	5	F	1-RH-Osteosclerosis central tarsal bone 2-LH–Bone spavin 3-Overlapping thoracic dorsal spinous process	1	94	182	R>L*	0.93	98	195	R>L*	1.46
17	TF	6	M	1-RH- Bone spavin 2-LH-Bone spavin 3-Lumbar pain	1	96	178	R>L*	1.03	97	196	R>L*	1.52
19	TF	4	M	1–LF–Healing tendinitis of superficial digital flexor tendon	1	96	126	R>L	0.98	97	188	R>L	1.32
24	SF	7	F	1–RF–Navicular disease	1	96	168	L>R	0.98	100	168	L>R	1.51
29	SF	8	G	Instruction riding horse	0	93	187	–	0.84	98	198	–	1.44
30	SF	9	G	Instruction riding horse	0	93	184	–	0.88	99	197	–	1.49
28	SF	11	G	Instruction riding horse	0	94	184	–	0.85	97	197	–	1.44
25	S	16	F	Instruction riding horse	0	97	191	–	0.97	97	196	–	1.66
31	AA	7	F	Competition horse	0	97	184	–	0.80	98	194	–	1.36
15	TF	4	M	Placed in Prix d'Amérique	0	98	126	–	0.88	98	198	–	1.56

Breed: S = Selle, SF = Selle Français, AA = Anglo-Arabe, TF = Trotteur Français, PaFi = Paso Fino, PaPe = Paso Peruvian.
Sex: G = Gelding, F = Female, M = Male.
Symmetry **(Sym)** and regularity **(Reg)** are expressed in %
Stride frequency **(SF)** is expressed in stride/s
Lat = side of maximum lateral acceleration during the early stance phase.
* The side of maximum lateral acceleration was inconsistent with the diagnosis of lameness.

put more load (Fig. 1). The horse reduced the lateral and medial acceleration during the support phase of its lame limb. On a total of 17 lame horses, it was possible to detect correctly the side of lameness in 13 cases by measuring the maximum lateral acceleration at mid-stance phase. This maximum was greater on the controlateral side of the lame limb (Tab. 1). The lameness side detection was not in keeping with the diagnosis established in 4 cases where the horses suffered from a hindlimb lameness of grade 1. In these cases, the maximum acceleration was always found on the left side.

Discussion

The locomotor test was easy to perform in veterinary pratice conditions and it was well accepted by the horse. One locomotor test took about 5 min to make a walk and trot recording and the data processing on a portable microcomputer (PC-386) took about 5 min. Acceleration measurement was considered to be very sensitive to detect small changes in locomotion kinetics and it has been successfully used in many lameness studies (*Buchner* et al. 1993, *Barrey* et al. 1994). The improvement of the technology for building accelerometers (micro-machined silicon piezoresistive accelerometers) allowed to use small, sensitive, light and low cost transducers which are well adapted for measuring biomechanical variables.

In order to obtain a good recording, the horse had to be quiet at a walk and trot in a natural and regular way. If it was excited, the stride frequency increased, especially at walk, and the regularity decreased. As it has been found previously, measurement of stride frequency did not characterize the lameness (*Deuel* et al. 1995). In our locomotor test, it was used to control the quietness of the horse.

In most cases, the results of the accelerometric test were consistent with the diagnosis of lameness. The gait symmetry and regularity were gradually affected by the degree of lameness. The analysis of the dorsoventral acceleration measured at the sternum by an autocorrelation procedure was able to detect simultaneously changes in temporal stride variables and vertical hoof forces. The autocorrelation takes into account a time series which seems to be more efficient than measuring discrete variables on the time-curves in order to find small disorders. This way, it was possible to detect both supporting limb lameness and swinging limb lameness. However, subtle lamenesses of grade 1 were often detected at walk by a decrease of regularity and symmetry but only the regularity of trot was affected. The problem of subtle lameness detection was also observed in kinematics studies of experimentally induced lameness where minor changes in stride characteristics were found (*Buchner* et al. 1995, *Deuel* et al. 1995). In contrast with the present study, the locomotion disorders were mainly observed at trot and not at walk (*Buchner* et al. 1995).

Tab. 2: Mean (SD) values of the gait parameters obtained for each grade of lameness.

	Symmetry (%)	Regularity (%)	Stride frequency (st./s)
WALK	p<0.05	p<0.05	NS
Grade 0	95.33 (2.05)a	176.00 (22.50)a	0.87 (0.05)
Grade 1	87.56 (8.93)a	174.39 (17.25)a	0.95 (0.08)
Grade 2	84.75 (2.86)ab	153.00 (22.45)ab	0.84 (0.04)
Grade 3	70.25 (26.41)b	146.00 (16.83)b	0.89 (0.10)
TROT	p<0.0001	p<0.0001	NS
Grade 0	97.83 (0.69) a	196.67 (1.37) a	1.49 (0.10)
Grade 1	97.72 (1.82) a	186.89 (11.77) a	1.49 (0.16)
Grade 2	96.75 (1.78) a	189.00 (8.45) a	1.49 (0.07)
Grade 3	78.00 (8.72) b*	157.00 (16.69) b*	1.50 (0.11)

The p value indicates the significance of the analysis of variance for each variable. The means followed by the same letter are not significantly different at $p<0.05$ or * $p<0.001$.
NS = The Stride frequency was not signicantly affected by the degree of lameness.

Some normal horses (grade 0) were detected asymmetric especially at the walk. The soundness of these horses should be suspected because of their age and status of instruction horses. These errors of classification underlines the difficulties in defining limits of normal asymmetries of the gaits. *Deuel* et al. (1995) found a bilateral asymmetry of temporal gait variables in old sound Dutch Warmblood mares. Hindlimb lamenesses were more difficult to detect than forelimb lamenesses. Location of the accelerometers over the sternum certainly explains this result because the hoof forces developed by the forelimbs directly influenced the kinetics of this part of the body. It has been demonstrated in a kinematic study that measurement of the accelerations of the croup gives specific information about the hindlimb lameness (*Buchner* et al. 1993).

The accelerometric device could indicate the side of the lameness. Analysis of the lateral acceleration was more difficult than the dorsoventral acceleration but it revealed in most of the cases the side of the lame limb. The maximum acceleration occurring at the beginning of the stance phase estimates the lateral component of the force applied to the center of gravity. In order to ease the lame limb, the horse automatically modifies its motions for decreasing both lateral and vertical components of the supporting hoof force. The errors of the side detection were associated with subtle hindlimb lameness of grade 1 which had probably less influence on the lateral acceleration of the sternum than other lamenesses. The lateral signal analysis should be improved in order to more acurately detect the side of lame limb.

It was concluded that the accelerometric device could be useful in veterinary pratice for quantifying the degree of lameness. The locomotor test performed with the accelerometric device fixed at the sternum could better detect lameness of the fore than the hind limb. The test at walk seemed to be more informative to detect subtle lameness. This accelerometric device opens several applications: to measure the progression of treated lameness and recovery after surgery; and to assess the soundness of the locomotor apparatus in an evaluation procedure such as pre-purchase examination or a veterinary control during competition.

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