Detection and localisation of unilateral hindlimb pathologies in cattle using the cow pedogram

Maher Alsaaod,[1] Esther Bucher,[1] Martina Feierabend,[2] Maria-Christina Haerdi-Landerer,[2] Adrian Steiner[1]

Limb pathologies are a major concern in cattle welfare. Visual assessment of the gait pattern is the standard technique for limb pathologies detection.[1 2] Shortened weight-bearing combined with prolonged swing-phase durations are typical of lameness caused by pathologies located in the digits. Stiff swing phase indicates a lameness caused by a pathology located in the proximal limb, as pain may result from muscle contraction and joint flexion.[3] The following steps include the clinical localisation of limb pathologies: (1) adspection of a cow while standing and walking; (2) clinical examination of the hoof including the use of hoof pincers; (3) manipulation of the affected limb using flexion tests; (4) palpation of the affected limb; (5) and diagnostic local analgesia or temporary claw block fixation.[4]

Detection of slightly lame cows and non-lame cows with limb pathologies and those with early limb pathologies is most challenging.[5] Therefore, the availability of a sensitive, objective tool to complement the clinical limb examination is highly desirable. A previous study showed that the cow pedogram can detect lameness caused by limb and claw pathologies with a very high accuracy.[6] The aims of this study were to evaluate the validity of the cow pedogram, first to detect hindlimb pathologies, including the digits and, secondly, to differentiate between pathologies located in the proximal versus distal limb.

The study was carried out at the Clinic for Ruminants, Vetsuisse-Faculty, University of Bern. The cow descriptions are included in table 1. Twelve dairy cattle that had been referred to the clinic between February and April 2016 for pathologies not related to the locomotor system, without clinical lameness and not affected by limb lesions were allocated to the control group (group C). Cows of group C were not subjected to abdominal surgery, and did not have clinical mastitis. Cows of the pathology group (group P; n=64) were referred to the clinic between October 2013 and August 2017 either for evaluation of a unilateral hindlimb pathology or for reasons not related to the locomotor system but revealed a unilateral limb pathology at thorough clinical examination. Pathologies of group P were either located in the area of the digit (up to and including the fetlock joint=LOC1; n=43) or proximal to the fetlock joint (LOC2; n=21) (table 2). The result of a thorough clinical limb examination of all four limbs, including the digits was used as the gold standard for group allocation. If indicated, this was complemented by a radiographic and/or ultrasonographic examination and/or synovial fluid analysis.

Before data were recorded, cows were equipped with two standalone 3D accelerometers (400 Hz; USB Accelerometer X16-4; Gulf Coast Data Concept), which were fitted at the level of the metatarsus III/IV to both hindlimbs. The gait cycle variables were extracted using the validated Cow-Gait-Analyzer as described by Alsaaod *et al*.[7] The pedogram parameters included the temporal events (kinematic outcome) relative stance-phase and swing-phase durations and the peaks (kinetic outcome) foot load and toe-off. All four parameters were calculated as the absolute difference across limbs within cow (Δ_{MT}). All cows were videotaped and blinded to group allocation and lesion, and locomotion was scored using a 1–5 numerical rating system.[2] The mean value of lameness score of two trained veterinary specialists was calculated.

For comparison between different groups (part I: group C v group P; part II: group C v group LOC1; part III group LOC1 v group LOC2) one-way analysis of variance was performed. A receiver operating characteristic

Veterinary Record (2019) doi: 10.1136/vr.105014

[1]Clinic for Ruminants, Vetsuisse-Faculty, University of Bern, Bern, Switzerland
[2]Institute of Agricultural Sciences, ETH Zurich, Zurich, Switzerland

E-mail for correspondence: Farm Animal Clinic, Vet Suisse, Bern 3012, Switzerland; maher.alsaaod@vetsuisse.unibe.ch

Provenance and peer review Not commissioned; externally peer reviewed.

Received May 15, 2018
Revised November 6, 2018
Accepted December 16, 2018

Table 1 Mean (±sd) of lactation number, milk yield, and body weight, number of animals per breed and median locomotion score (including the range) for cattle of group C (no limb pathologies), group LOC1 (distal hindlimb locations, up to and including the fetlock joint) and group LOC2 (proximal to the fetlock joint)

	Group C; n=12	Group LOC1; n=43	Group LOC2; n=21
Lactation number	2.58 (±1.31)	2.97 (±2.05)	2.63 (±1.95)
Milk yield (kg)	30.5 (±8.87)	25.12 (±8.55)	28.07 (±14.82)
Bodyweight (kg)	632.36 (±94.01)	613.29 (±102.54)	536.65 (±171.31)
Breed	SF (5), RH (4), HF (2), RG (1)	ER (10), HF (8), SF (7), SI (6), RH (5), BV (4), others (3)	HF (7), ER (7), RH (3), SF (3), JE (1)
Locomotion score	1.75 (±0.29), range (1.17–2.17)	3.25 (±0.60), range (1.83–5)	3.17 (±1), range (2–5)

In the row 'Breed', the numbers in brackets refer to the number of the cows.
BV, Braunvieh; ER, Eringer; HF, Holstein-Friesian; JE, Jersey; RG, Rhätisches Grauvieh; RH, Red Holstein; SF, Swiss Fleckvieh; SI, Simmental.

analysis was used to determine the performance of the pedogram at the cow level. The change of the stance and swing phases (difference value across the limbs) is analogous. Therefore, the statistical analyses for both variables were performed, but only the relative stance phase was reported. The gait cycle variables of the cow pedogram were calculated as the absolute difference across the limbs. All data were analysed using the software package NCSS10 (NCSS, Kaysville, UT). Post hoc power calculation was performed using G*Power V.3.1.9.2 (http://www.gpower.hhu.de).

A significant difference between group C and group P and between group C and group LOC1 was found for all gait cycle variables (table 3). Using the threshold of 2.09 per cent for Δ_{MT} of relative stance-phase duration, cows with unilateral hindlimb pathologies of group P or LOC1 were detected with the sensitivity of 100 per cent and a specificity of 100 per cent (table 4).

Table 2 Clinical findings of limb pathologies in cattle of groups LOC1 and LOC2. The clinical examination was used as the gold standard for group allocation

	Group LOC1	Group LOC2
Pathological findings	Osteitis of P3 (12), tendovaginitis of 'CDFTS' (7), BA (3), fracture of P3 (3), DS (3), SU (2), septic arthritis of 'DIJ' (2), claw horn fissure (2), IP (2), WLA (2), WLD (2), IP (1), osteoarthritis of the fetlock joint (1) and phlegmon in the area of the fetlock (1)	Septic arthritis of 'TTJ' (6), cortical sequestrum of metatarsus III/IV (2), osteoarthrosis of 'TTJ' (2), osteoarthrosis of 'TMJ' (1), septic synovitis of common tendon sheath of tibialis caudalis and flexor digitalis longus muscle (1), epiphysitis of metatarsus III/IV (1), soft tissue swelling lateral to the hock joint (1), rupture of the cranial cruciate ligament (3), septic arthritis of the medial femorotibial joint (1), septic coxarthritis (1), soft tissue swelling distal to the stifle joint (1) fracture of os ilium (1)

BA, bulb abscess; CDFTS, common digital flexor tendon sheath; DIJ, distal interphalangeal joint; DS, double sole; IP, interdigital phlegmon; SU, sole ulcer; TMJ, tarsometatarsal joint; TTJ, tibiotarsal joint; WLA, white-line abscess; WLD, white-line disease.

Table 3 Mean (SEM) differences across metatarsi III/IV (ΔMT) for kinematic (temporal=relative stance-phase duration) and kinetic (peaks=foot load and toe-off) pedogram variables between no pathology cows and such with pathologies of various hindlimb locations. *Part I: group C v group P; part II: group C v group LOC1; part III: group LOC1 v group LOC2

		Part I				Part II				Part III			
		Group C† (n=12)		Group P‡ (n=64)		Group C (n=12)		LOC1§ (n=43)		LOC1 (n=43)		LOC2¶ (n=21)	
	Variable	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Kinematic (temporal)	Stance phase (%)**	0.91††	5.448	21.49‡‡	2.23	0.91††	5.342	24.81‡‡	2.822	24.81††	3.083	14.70‡‡	4.118
Kinetic (peak)	Foot load (g)	0.76††	1.211	5.13‡‡	0.528	0.76††	1.203	5.85‡‡	0.646	5.85††	0.674	3.641‡‡	0.978
	Toe-off (g)	0.34††	0.470	2.10‡‡	0.199	0.34††	0.467	2.24‡‡	0.246	2.24	0.269	1.80	0.375

*The pedogram variable was calculated as the difference across limbs within cows.
†Group C: cows without clinical pathology of the locomotor tract, skin score less than 1 (no alteration or hairless patch, skin unaltered without swelling).[10]
‡Group P: cows with limb pathologies at LOC1 or LOC2.
§LOC1: cows with digit pathologies (including pathologies of the fetlock joint and/or the common digital flexor tendon sheath).
¶LOC2: cows with proximal limb pathologies (proximal to the fetlock joint).
**Proportion of time (%) that the foot is in contact with the ground relative to the total gait cycle duration (interval between foot load peak and toe-off peak).[6 7]
††,‡‡Within each part (I, II, III), means with different superscripts within rows differ significantly ($P<0.05$).

Table 4 Receiver operating characteristics (ROC) of the mean differences for kinematic (stance-phase duration) and kinetic pedogram variables (foot load, toe-off) in cows with no pathologies (group C) and such with pathologies (group P) of various hindlimb locations

		Part I				Part II				Part III			
	Variable	Cut-off	SN (%)	SP (%)	AUC	Cut-off	SN (%)	SP (%)	AUC	Cut-off	SN (%)	SP (%)	AUC
Kinematic (temporal)	Stance phase (%)	2.09	100	100	1.00	2.09	100	100	1.00	17.64	40.0	42.1	0.35
Kinetic (peak)	Foot load (g)	1.65	75.5	91.7	0.84	2.56	74.4	100	0.87	3.89	40.0	42.1	0.36
	Toe-off (g)	0.75	77.9	94.2	0.84	1.00	81.4	100	0.89	1.74	53.3	50.0	0.46

SN, sensitivity; SP, specificity.

Relative stance-phase duration and peak foot load were significantly different between LOC1 and LOC2 (table 3). Post hoc power analysis for not significant variables was 0.95 for toe-off peak. However, the performance of the cow pedogram was insufficient to differentiate within group P between LOC1 and LOC2 (table 4).

The kinematic and kinetic measurements were performed at the hindlimbs, because hoof disorders and signs of lameness occur much more commonly in hind hooves in cattle.[8] The groups were classified according to the presence of limb pathologies rather than the locomotion scoring as some limb pathologies at a certain stage do not cause any visible lameness.[9]

In the previous study with a much lower number of cows,[6] the cut-off value for Δ_{MT} of relative stance-phase duration was determined to be at 2.53 per cent. We now additionally determined sensitivity (96.22 per cent) and specificity (100 per cent) when using this established cut-off value and determined a new cut-off value (2.09 per cent) with higher sensitivity using the whole data set of this study.

Δ_{MT} of the relative stance-phase duration and peak foot load was significantly higher in LOC1 as compared with LOC2, indicating that the digits of LOC1 group showed shorter stance-phase duration and less kinetic force at foot load as compared with digits of LOC2 group. This is in agreement with the clinical experience.[3] Proximal pathologies (LOC2; including pathologies of the tarsal area) may cause either swing-phase or stance-phase alterations or a combination thereof and are, therefore, less uniform than the distally located pathologies, causing mainly stance-phase alterations. This is probably the reason why the pedogram does not represent the ideal tool to distinguish between lameness of LOC1 versus LOC2.

In summary, the cow pedogram represents a highly sensitive tool for the detection of cows with unilateral hindlimb pathologies, including cows with hindlimb pathologies but without clinically visible lameness. However, the tested pedogram variables were not suitable to differentiate between distally and proximally located pathologies.

Acknowledgements This study was generously supported by grants of the 'Fondation Sur-La-Croix' (Basel, Switzerland).

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Ethics approval The study protocol was approved by the animal experimentation committee of the canton of Bern, Switzerland (permission number 25601).

References

1 Sprecher DJ, Hostetler DE, Kaneene JB. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. *Theriogenology* 1997;47:1179–87.
2 Flower FC, Weary DM. Effect of hoof pathologies on subjective assessments of dairy cow gait. *J Dairy Sci* 2006;89:139–46.
3 Greenough PR, Weaver AD. Lameness in cattle. 3rd edn. London: W.B. Saunders Co, 1997.
4 Steiner A. Clinical and imaging procedures for lameness diagnosis in cattle. XXV Jubilee World Buiatrics Congress. Budapest, Hungary: WBC, 2008:104–6.
5 Rutten CJ, Velthuis AGJ, Steeneveld W, *et al*. Invited review: sensors to support health management on dairy farms. *J Dairy Sci* 2013;96:1928–52.
6 Alsaaod M, Luternauer M, Hausegger T, *et al*. The cow pedogram-Analysis of gait cycle variables allows the detection of lameness and foot pathologies. *J Dairy Sci* 2017;100:1417–26.
7 Alsaaod M, Kredel R, Hofer B, *et al*. Technical note: Validation of a semi-automated software tool to determine gait-cycle variables in dairy cows. *J Dairy Sci* 2017;100:4897–902.
8 Solano L, Barkema HW, Mason S, *et al*. Prevalence and distribution of foot lesions in dairy cattle in Alberta, Canada. *J Dairy Sci* 2016;99:6828–41.
9 Tadich N, Flor E, Green L. Associations between hoof lesions and locomotion score in 1098 unsound dairy cows. *Vet J* 2010;184:60–5.
10 Weary DM, Taszkun I. Hock lesions and free-stall design. *J Dairy Sci* 2000;83:697–702.