Analysis of six spatiotemporal variables derived from pressure mat measurements:

exploring their use as discriminative diagnostic tool for detecting piglet lameness

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Abstract

Lameness is one of the main problems in modern pig industry. Apart from economic losses due to lower productivity and survivability, lameness severely impairs the animal's welfare. In pigs lameness is often underdiagnosed due to the limited time spent observing individual animals and the absence of a fast, sensitive and appropriate diagnostic tool. Recent studies show promising results using different limb pressures obtained by a pressure mat in detecting lameness. In the present study pressure mat analysis has provided data on the variables stance duration, step duration, step length, stride duration, stride length and stance percentage. After training sound control (n=21) and lame piglets (n=9) to trot over the pressure mat, two valid runs were registered and the data analysed using the purpose build program Pawlabeling. Average left/right asymmetry indices (ASI) for the fore- and hind limbs separately for each of the six variables were analysed in a Mixed Model using IBM SPSS 21 with piglet as random factor. Significantly higher ASIs were found in both the affected and non-affected side (front/hind) of lame piglets compared to the controls for stance duration. Remarkably, the non-effected side of lame piglets showed the highest ASI in all six variables in comparison with the ASI's of the control piglets. This might be due to the less adequate compensation between ipsilateral compared to contralateral limbs. No differences could be found for the ASIs of stride duration and stride length. Although these four pressure mat variables appear to be able to discriminate between lame and sound piglets, the practical applicability remains to be determined and is expected to be poor, due to the complexity of data analysis and lack of reference values.

Background

Following fertility disorders, lameness is one of the main problems in modern pig industry**,** accounting for 10% to 20% of all removals[1,2]. A cross-sectional study in the United Kingdom revealed an estimated prevalence of lameness of 14.4% in pregnant gilts, 16.9% in pregnant sows and 19.7% in finishing pigs[3]. Lameness in pigs is mostly associated with pathologies or injuries in the foot itself, the bones or the joints, caused by infectious arthritis, physical injuries or osteochondrosis[2,4].

Apart from the monetary losses due to the lower productivity, high costs for treatment and lower life expectancies, lameness is a problem that severely impairs the animal's welfare.[2] The animals might suffer from pain related to the cause of lameness and the accompanied reduced mobility. The problem is notoriously underdiagnosed in industrially kept animals because of the limited space they can walk in and the shortage of time farmers can spend to observe individual animals. Undiagnosed lameness can expend unto a level at which the animal is no longer able to stand up at all, to get dehydrated and undernourished, become in danger of being overrun by its penmates and get additional trauma. Because of the large negative impact of the problem on animal as well as farmer, it is important to develop and validate a practical, fast and sensitive tool for diagnosing and treating lameness as early as possible.

Currently there are several possibilities to detect lameness, but they are either time consuming (kinematic analysis, clawprints in clay), or subjective to some degree (visual lameness scoring, accelerometers)[5]. The simplest technique in use is visual scoring. Main et al[6] created a scoring system that incorporates gait characteristics as well as posture and behavioural aspects. This method has been shown to be highly replicable between trained observers, whereas the inter-rater reliability was poor between untrained observers. Consequently, this diagnostic tool is unsuited for occasional clinical investigations. Confirmatory studies in dogs and horses have also shown visual methods to be inherent to subjectivity, mainly due to observer bias and (lack of) scoring experience[6-10]. Especially subtle changes in locomotion occurring in early stages, such as weight bearing or posture, can easily be overlooked.

More objective methods involve kinematics and kinetics, that have been widely studied in horses and cattle. Kinematics has previously been used in pigs as well to study the effect of different floor surfaces on locomotion[5,11] and to quantify lameness in sows[5]. Yet, this method is rather complicated and time consuming and is unsuitable in practical situations.

Kinetics and footprint analysis use force plates and pressure mats respectively to determine gait patterns and weight distribution between and within feet. A force plate is not able to distinguish between different feet when being on the ground simultaneously. Proper data collection therefore demands the use of multiple plates and is very time consuming. Footprint analysis using pressure mats is not subjected to these factors due to the dense array of pressure sensors with a high measuring frequency. They collect kinetic as well as spatiotemporal data of simultaneous and consecutive contacts. The knowledge on footprint analysis enhances fast. It has been shown useful to evaluate gait patterns and pressure profiles in sound horses[12,13], cows[14], dogs[15], cats[16] and sheep[17]. It has already been used to asses lameness in cows[18] and dogs[19,20]. Most studies using pressure mats focus on pressure profiles only. The knowledge about alterations of parameters like stance time and percentage, step duration and length and stride duration and length due to lameness is still limited.

Aim of the present study: we focussed on several locomotion parameters (stance time and percentage, step duration and length and stride duration and length) of both healthy and lame three- to ten ten-week-old piglets. The pigs were trained to walk and trot on an RS Footscan plate which collected the data. We evaluated the asymmetry indices (ASI's) of these variables to determine whether this method was able to discriminate reliably between lame (front vs. hind) and sound piglets.

Materials and methods

The study was reviewed and approved by the local ethical committee of Utrecht University (DEC no 2012.III.05.04), The Netherlands, and was conducted in accordance with the recommendations of the EU directive 86/609/EEC. All effort was taken to minimize the number of animals used and their suffering.

Materials

Animals

A total of 46 *Topigs 20* pigs was included in this study. The control group consisted of 24 (12 boars, 12 sows) healthy pigs ranging in age from 6 to 7 weeks supplied by a commercial breeding farm. The group of clinically lame pigs consisted of 22 3- to 10-week-old animals (12 boars, 10 sows) . The pigs were transported to the animal facility of the Department of Farm Animal Health, Veterinary Faculty, Utrecht University. The control group was brought in in one batch and was allowed to acclimatise for 1 week. The trial group consisted of several batches and enrolled the experiments after one day of acclimatisation to the new environment. At the end of this study, the same pigs were used in another study to assess the effect of pain relief on welfare and gait patterns.

Data recording

Gait parameters were determined by kinetic analysis, using a pressure mat (Footscan® 3D Gait Scientific 2 m, supplier: RSscan Internaltional, Olen, Belgium). The active sensor surface of this mat measured 195x32 cm, containing 16384 sensors (2.6 sensors per cm^2), with a sensitivity of 0.27-127 n/cm^2 and a measuring frequency of 126 Hz. A few modifications, as previously described by Meijer et al.[21], were made to the test setting in order to ensure the pigs comfort and prevent them from leaning against the walls. The mat was connected to a laptop with dedicated software (Footscan Scientific Gait 7 gait 2nd generation, RSscan International, Olen, Belgium). The mat was calibrated according the manufacturer's instructions.

<u>Methods</u>

Housing

At arrival, within both groups, the pigs were randomly divided over 3 pens in the research facility of Utrecht University. All pens had closed concrete floor on which sawdust was provided as bedding material. The pens were similar in surface, ranging from 3,68 to 3,96 m^2, and contained no more than 8 pigs, providing them enough space according to EU legislation (0,35m^2/10-20kg pig). The animals were fed at libitum (Groeiporco, De Heus Animal Nutrition, Ede, The Netherlands) and had *ad libitum* access to water. The ambient temperature in the stalls was 24°C. Additional heat lamps were provided if needed. The pigs were exposed to both daylight and artificial lighting from 7 a.m. to 6 p.m. (11 hours a day). Toys such as metal chains and plastic balls were provided during the entire experiment.

Quantification of lameness

To establish the absence or degree of lameness, both visual scoring and footscan analysis were used. Visual scoring was performed by a trained veterinarian, according to a modified version of the system validated by Main et al.[6]. Footscan analysis provided information on stance duration, stance percentage, step length, step duration, stride length and stride duration (see Fig. 1). Stance duration is defined as the time the limb is in contact with the ground, step length is the travelled distance between the right and left limb with step duration being the time needed for this distance. The stride length corresponds to the distance between two successive limb placements of the same limb, the time needed for this movement is called the stride duration. Stance percentage is the ratio between the time the limb is in contact with the ground compared to the swing phase of that limb.

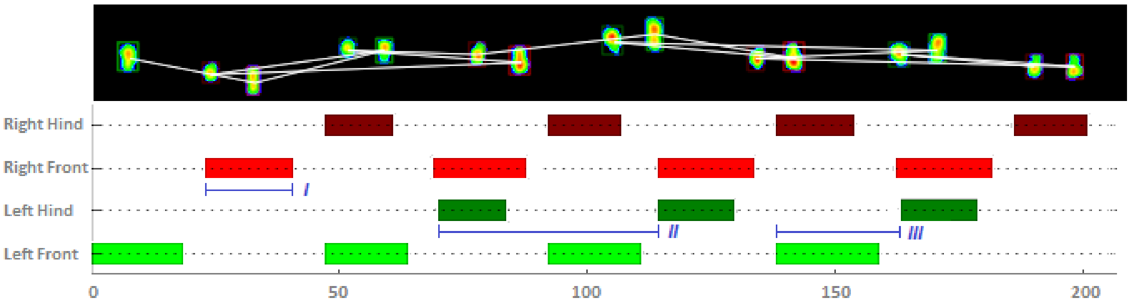

Figure 1: Example of a gait pattern (left-right) as visualised using the purpose-build program Pawlabeling, x-axis representing distance (cm). I: stance duration, II: Stride length/stride duration, III: Step length/step duration

Procedure

After familiarisation to the test apparatus training started. The animals were trained to trot over the plate in a straight line without stopping, using treats as a reward when the animal performed a correct run (see below). Training ended when a pig had performed 3 correct runs. A training session never exceeded 10 minutes, even if no correct runs were performed. In 2-3 training sessions all pigs appeared to be able to perform the desired behaviour.

To minimize handling-associated stress, the pigs were trained and later on tested in the order they presented themselves in. After letting an individual out of its pen, it walked freely and by itself to the testing area and into the holding pen at the beginning of the pressure mat. As during training, pigs were also rewarded for each correct run during the experiment.

A correct run had to fulfil the following criteria to be considered valid and to be included in the study: the pig had to trot the entire length of the runway in a straight line, without stopping and looking straight ahead. The lame pigs appeared not to be able to trot, criteria for this group were adjusted by replacing the criterium trot for walk. The other criteria could still be met. All of these criteria were judged by two observers and at least 2 valid runs per pig were collected. Velocity was recorded by the pressure mat.

After recording the data for this study, the piglets performed in an additional study. After that study had been completed, the pigs were euthanized by first sufficiently sedating them with 2 mg/kg Azaperone IM (Stresnil, Elanco Animal Health, Greenfield, USA) followed by 200 mg/kg Pentobarbital IC (Euthanimal, Alfasan, Woerden, The Netherlands). Hereafter, the pigs were necropsied at the Department of Pathobiology of the Faculty of Veterinary Medicine of Utrecht University. Gross pathology confirmed the pigs' general health at the time of death. Specific attention was paid to the limb joints. They were dissected free and inspected for any macroscopic signs of joint disease. The pigs in the control group showed no macroscopic changes in any of the joints, in the lame pigs clinical diagnosis was confirmed by macroscopic changes in the affected joint.

Data analysis

To ensure the reliability of the data, pigs with less than 2 completed runs and pigs with less than 8 contacts (each paw twice) per run were excluded from the analysis. This left 22 control and 9 lame pigs for data analysis. (see Fig. 2)

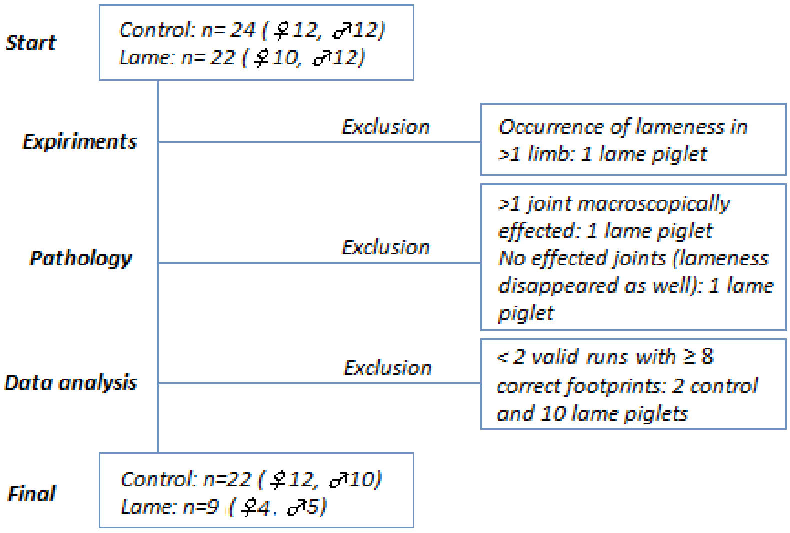

Figure 2: Flow diagram of the process through the phases of this study

Claw strikes from the 2 valid runs were automatically recognised by the purpose-built program Pawlabeling[22] and manually assigned to the left fore (LF), right fore (RF), left hind (LH) and right hind (RH) limb. For every pig means for step length, step duration, stance duration and stride duration were calculated for each paw in each of the 2 valid runs. Fore and hind limb asymmetry indices (ASI) of all variables were calculated using the following formula[21,23]

$$ASI = \frac{L-R}{0{,}5(L+R)} * 100$$

Using this method, the ASI ranges between the values -200% and 200% with 0% indicating perfect symmetry. Positive or negative deviations indicate a relatively higher loading of the left or right limb respectively. For further statistical analysis, the absolute value of the ASI's was used, removing the distinction between right- or left-sided asymmetry because of the limited number of lame animals and the uneven deviation of left and right sided lameness among them. The final dataset contained 4 ASI's per variable per piglet, consisting of one hind side and one front side ASI per run for each of the two runs.

Statistics

All data, except stride length, had to be [$\log_{10}$ (y+1)]-transformed to meet normality assumptions, because some piglets had asymmetry indices equal to 0. Pearson correlations are calculated between the several asymmetry indices among each other and in relation to gender, weight and velocity. For analysis, the data of lame piglets were subdivided into groups, ASI's originating from the affected and non-affected side (e.g. in case of forelimb lameness, the front side ASI's were considered as affected side data, hind side ASI's of that individual as non-affected side data). A linear mixed effects model was used to evaluate the effect of lameness on the different dependent variables (ASI's) with piglet set as random effect and group as fixed factor, except for the variable 'stride length' which was not normally-distributed, even after $\log_{10}$ transformation. Consequently, this variable was analysed using a general linear model with group as fixed factor. Geometric means were calculated using the outcome of the models. Data were analysed using SPSS statistics 21 (IBM), with statistical significance set at $p < 0.05$. To assess variability between the different runs of one piglet, intra-class correlations were calculated and interpreted according to Shrout and Fleiss[24].

Results

Asymmetry indices

Asymmetry indices are thought to be least influenced by variables such as velocity, gender and weight because of the intra-animal correction for those factors, resulting in a left-right ratio. To determine the influence of these factors, Pearson correlations are calculated between all six pressure mat variables and the variables gender, weight and velocity.

None of the six pressure mat variables in the control group showed a high correlation with the variable gender (Pearson correlations: -0.117 – 0.078, all with p>0.05). Except for step length, the same applies for the variable weight (Pearson correlations: -0,119 – 0,124). According to Boot et al[25], the correlation between the asymmetry index for step length and weight can be considered to be weak-mildly positive (r=0.301, n=88, p=0.004). Velocity only showed a significant weak positive correlation with the asymmetry index of step duration (r=0.287, n=88, p=0.007), the other five variables showed no significant or high correlations with velocity (Pearson correlation: -0.137 – 0.122).

The ASIs for lame piglets showed no correlation with gender, but weak-mild negative correlations between stance duration (r=-0.429, n=36, p=0.009), step duration (r=-0.397, n=36, p=0.016), stride duration (r=-0.344, n=36, p=0.040) and stance percentage (r=-0.343, n=36, p=0.041). Just as in the control piglets, a weak-mildly positive correlation between velocity and the ASI step duration (r=0.362, n=36, p=0.030) was found.

Pressure mat variables

The within pressure mat variable correlations are shown in Table 1. Correlations were considered relevant if p<0.05 and p>0.3 or if p>0.05 in combination with an r>0.5. According to Boot et al., the two relevant correlations found in the control group between ASI stride duration and ASI stance duration (r=0.323, n=88, p=0.002) and between ASI Stance percentage and ASI stance duration (r=0.485, n=88, p=0.000) are both weak-mildly positive. Lame piglets showed more significant correlations as can be seen in Table 1. The correlation between ASI stance percentage and ASI stance duration can be specified as strong (r=0.839, n=36 , p=0.000). The other relevant correlations can be classified as weak-mildly positive.

As shown in Table 2, the observed higher absolute asymmetry indices of the hind limbs are not significantly enlarged compared to those of the front limbs.

ASI Stance duration

Asymmetry indices for stance duration were significantly different for lame piglets compared to those in the control group. The asymmetry in stance duration between left and right compared to those of the control piglets appeared to be the significantly higher at the non-affected side (front/hind) of the lame piglets (+0.371; 95%CI=0.175–0.567; p = 0.001) as well as in the affected side (+0.227; 95%CI=0.06–0.492; p=0.013). No significant difference in ASI stance duration was found between the affected and non-affected side (front/hind) of lame piglets (+0.094; 95%CI=-0.171 – 0.359; p = 0.475). This reveals the geometric mean of the ASI stance duration in the affected and non-affected side of lame piglets to be respectively 189.2% and 344.3% larger than the geometric mean of the control sound piglets. (Fig. 3, Table 3)

Table 1: Overview of the Pearson correlations within the 6 pressure mat variables. Relevant correlations (r>0.3 and p<0.05 or r>0.5 and p>0.05) are bolded.

Pearson correlation			ASI stance duration	ASI step duration	ASI step length	ASI stride duration	ASI stride length
ASI step duration	Control	r	0.206	X			
		p<	0.054	X			
	Lame	r	**0.727**	X			
		p<	**0.000**	X			
	C+L	r	**0.479**	X			
		p<	**0.000**	X			
ASI step length	Control	r	0.229	0.191	X		
		p<	0.032	0.074	X		
	Lame	r	0.311	0.138	X		
		p<	0.065	0.421	X		
	C+L	r	**0.392**	**0.351**	X		
		p<	**0.000**	**0.000**	X		
ASI stride duration	Control	r	**0.323**	0.258	**0.318**	X	
		p<	**0.002**	0.015	**0.003**	X	
	Lame	r	**0.336**	0.298	0.170	X	
		p<	**0.045**	0.078	0.320	X	
	C+L	r	**0.372**	**0.327**	**0.318**	X	
		p<	**0.000**	**0.000**	**0.000**	X	
ASI stride length	Control	r	0.054	0.147	0.089	**0.257**	X
		p<	0.618	0.172	0.411	**0.016**	X
	Lame	r	0.265	0.229	0.308	0.163	X
		p<	0.118	0.179	0.067	0.343	X
	C+L	r	0.114	0.149	0.151	0.217	X
		p<	0.206	0.099	0.094	0.015	x
ASI stance percentage	Control	r	0.485	0.274	0.100	-0.026	-0.071
		p<	0.000	0.010	0.354	0.811	0.509
	Lame	r	0.839	0.785	0.344	0.344	0.294
		p<	0.000	0.000	0.040	0.040	0.082
	C+L	r	0.671	0.567	0.400	0.179	0.038
		p<	0.000	0.000	0.000	0.047	0.672

ASI Step duration

The asymmetry indices for step duration were significantly different for lame piglets' affected (+0.380; 95%CI=0.120–0.640; p=0.006) and non-affected (+0.482; 95%CI=0.245–0.718; p=0.000) side compared to those in the control group. No significant difference was found between the asymmetry indices of the non-affected and affected side of lame piglets (+ 0.101; 95%CI=-0.219–0.422; p = 0.524). The geometric means of the ASI of step duration in the affected and non-affected side of lame piglets are respectively 239.9% and 303.4% larger compared to the geometric mean of the control piglets. (Fig. 3, Table 3)

Table 2: Fore and hind limb absolute values for ASI's (mean ± SEM) for stance duration, step duration, step length, stride duration, stride length and stance percentage. The last column shows the associated probabilities of the observed differences.

Variable	Group	Front	Hind	Significance
ASI stance duration	Control	7.836 ± 0.877	8.796 ± 0.943	p = 0.455
	Lame	17.258 ± 4.430	24.035 ± 3.384	p = 0.233
ASI step duration	Control	9.930 ± 1.094	11.913 ± 1.726	p = 0.333
	Lame	29.071 ± 8.199	37.904 ± 6.015	p = 0.391
ASI step length	Control	4.877 ± 0.595	6.894 ± 0.999	p = 0.087
	Lame	18.591 ± 4.283	26.702 ± 5.891	p = 0.274
ASI stride duration	Control	3.866 ± 0.413	4.533 ± 0.710	p = 0.414
	Lame	5.715 ± 1.134	6.455 ± 0.942	p = 0.616
ASI stride length	Control	2.378 ± 0.293	2.511 ± 0.298	p = 0.746
	Lame	2.871 ± 0.663	2.370 ± 0.516	p = 0.549
ASI stance percentage	Control	4.786 ± 0.604	6.352 ± 0.762	p = 0.111
	Lame	16.149 ± 4.207	23.636 ± 3.479	p = 0.179

ASI Step length

The asymmetry indices for step length significantly differed between the non-affected side of lame piglets and the control piglets (+0.602; 95%CI=0.390–0.815; p=0.000), but failed to reach significance for the affected side of lame piglets versus control piglets (+0.228; 95%CI=-0.004–0.461; p=0.054). The asymmetry index for step length appeared to be significantly higher in the non-affected side of lame piglets compared to the affected side (+0.374; 95%CI=0.0087–0.661; p=0.012). The geometric mean of the non-affected side of lame piglets is 399.9% larger than the one of the sound controls and 236.6% larger than the ASI of the affected side of lame piglets. The non-significant higher geometric mean of the affected side of lame piglets compared to the one of control piglets is 169.0%. (Figure 3, table 3)

ASI Stride duration and stride length

The lame piglets did seem to have slightly enlarged asymmetry indices for stride duration compared to those of the control piglets but none of these differences appeared to be significant (control vs. non-affected side of lame piglets: +0.154; 95%CI=-0.018–0.325; p=0.077 and control vs. affected side of lame piglets: +0.123; 95%CI=- 0.065–0.311; p=0.191). In addition, no significant difference in ASI stride duration within the lame piglets was found when comparing the affected and non-affected side (+0.302; 95%CI=-0.202–0.262; p=0.793). (Fig. 3, Table 3)

No significant differences were found for the asymmetry indices for stride length. This variable was the only one that showed higher asymmetry indices for the control compared to the affected side of lame piglets (-0.050;95%CI=-0.187–0.086; p=0.465). The non-effected side showed almost similar ASI values compared to the control values (+0.026; 95%CI = -0.098 – 0.150; p=0.681). Additionally, no significant difference between the effected and non-effected side of lame piglets could be detected (+0.056; 95%CI=-0.092–0.244; p=0.371). (Fig. 3, Table 3)

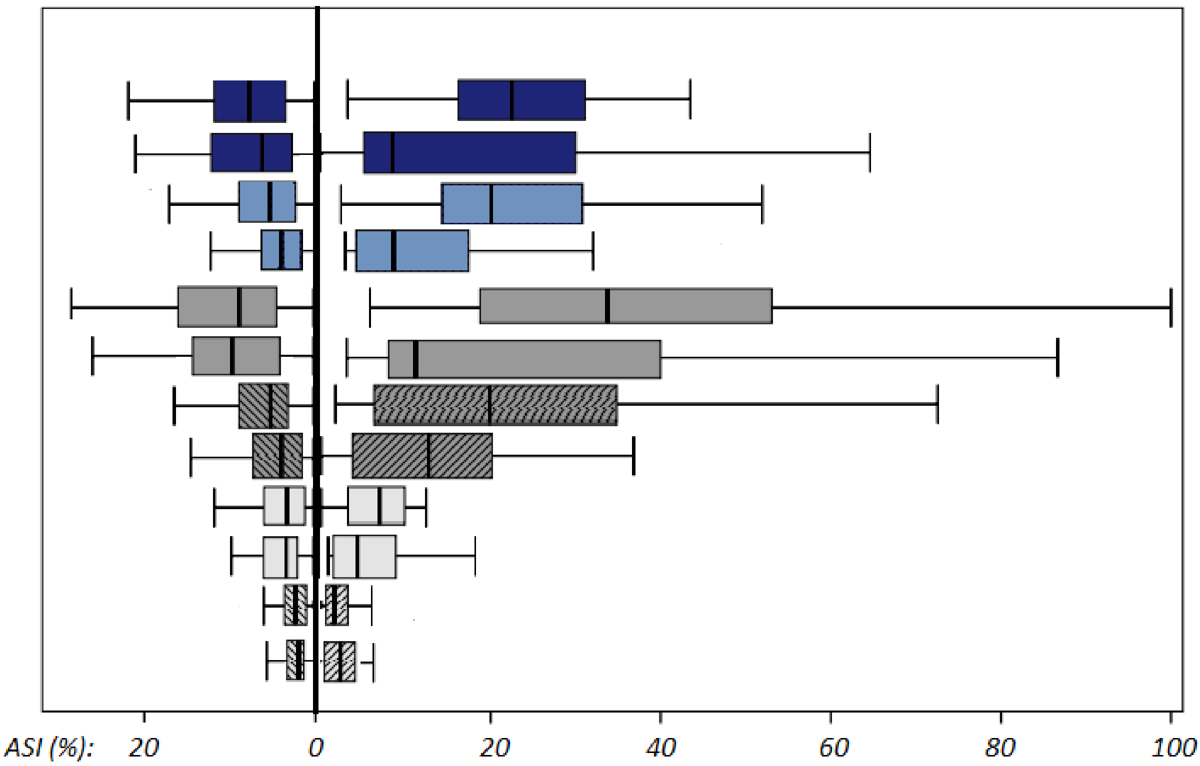

Figure 3: Absolute values for hind limb (first bar) and forelimb (second bar) ASI's (mean ± CI95%) for stance duration (plain dark blue), stance percentage (striped light blue), step duration (plain grey), step length (striped grey), stride duration (plain light grey) and stride length (striped light grey) separated for control and lame piglets, left and right respectively.

<u>ASI Stance percentage</u>

A significant difference in ASI stance percentage was found between control and lame piglets. The non-effected side of lame piglets again showed a higher difference compared to the control (+0.553; 95%CI=0.368–0.739; p=0.000) than the effected side of lame piglets (+0.388; 95%C=0.185–0.591; p=0.000). In accordance with the previous results, the non-effected side appeared to have a non-significant higher ASI compared to the affected side of lame piglets. This impression, however, was not confirmed statistically (+0.165; 95%CI=-0.085–0.416; p=0.188. The geometric mean of the non-affected and affected side of lame piglets is 357.3% and 244.3% respectively when compared to ASI values of control piglets. (Fig. 3, Table 3)

Table 3: Estimates, significance, 95% confidence intervals and the calculated geometric means (10^estimate) of the differences between the two sides of lame piglets compared to the control piglets, shown for each pressure mat variable separately. Significant differences are printed bold.

Variable		Non-affected side lame piglets	Affected side lame piglets
ASI stance duration	Estimate	+0.371	+0.277
	CI 95%	0.175 – 0.567	0.06 – 0.492
	p-value	**0.001**	**0.013**
	Geometric mean	344.4%	189.2%
ASI step duration	Estimate	+0.482	+0.380
	CI 95%	0.245 – 0.718	0.120 – 0.640
	p-value	**0.000**	**0.006**
	Geometric mean	303.4%	239.9%
ASI step length	Estimate	+0.602	+0.228
	CI 95%	0.390 – 0.815	-0.004 – 0.461
	p-value	**0.000**	0.054
	Geometric mean	399.9%	169%
ASI stride duration	Estimate	+0.154	+0.123
	CI 95%	-0.018 – 0.325	-0.065 – 0.311
	p-value	0.077	0.191
	Geometric mean	142.6%	132.7%
ASI stride length	Estimate	+0.026	-0.050
	CI 95%	-0.098 – 0.150	-0.187 – 0.086
	p-value	0.681	0.465
	Geometric mean	106.2%	89.1%
ASI stance percentage	Estimate	+0.553	+0.338
	CI 95%	0.368 – 0.739	0.185 – 0.591
	p-value	**0.000**	**0.000**
	Geometric mean	357.3%	244.3%

Replicability

Intra-class correlations (ICC) between runs were poor. ICC for ASI was the lowest for stance time (0.033), followed by stance percentage (0.038. ASI step length was highest with 0.168. This indicates a large variance within animals and poor replicability.

Discussion

This study is the first to explore the use of the pressure mat variables stance duration, step duration, step length, stride duration, stride length and stance percentage as a diagnostic tool for lameness in pigs. Collecting a sufficient amount of valid runs (n=3) showed to be fast and efficient, with an average time needed per piglet of 10 minutes. Data analysis however appeared to be a more time-consuming process, since the software used was designed for human gait analysis and thus unable to distinguish footprints of quadrupeds. The footprints had to be manually assigned left front, right front, left hind and right hind. Hereafter, the purpose build program 'Pawlabeling' checked the runs for discrepancies and calculated the ASI's automatically per run.

Asymmetry indices

Symmetry is often considered a characteristic of normal gait, consequently high asymmetry indices might indicate disturbances in gait pattern. In humans symmetry indices are used as diagnostic tools, indicators of gait pathology and in monitoring the results of treatments. [26] The use of asymmetry indices obtained with a 3D kinematic analysis system showed to be sensitive enough to distinguish between different degrees of lameness in horses.[27] In dogs the asymmetry indices have also been used to diagnose mild hind limb lameness in walk and trot.[28] Although this study by Voss et al.[28] showed promising results for analysis in trot rather that in walk, another study showed a certain degree of asymmetry was also detected in sound dogs.[29] Until now, it is still uncertain how much asymmetry may be considered normal and which variables best express gait symmetry and thus provide the best discriminators between sound and lame animals.

Therefore, in this study the differences in asymmetry indices were studied in both sound and lame piglets. Asymmetry indices are considered to be least influenced by variables such as velocity, gender and weight because of the intra-subject correction by calculating a left/right ratio. However, the degree to which ASI's might be sensitive to these factors has never been studied. In this study we looked for correlations between the different asymmetry indices and the three variables mentioned. In accordance with a study on the influence of gender on gait characteristics in cats[16], in our study also no correlation was detected between the different ASI's and gender. We did however find significant correlations between the ASI for step length and weight and between the ASI for step duration and velocity in control as well as in lame piglets. Although these correlations can be considered weak to mild and weak positive respectively[25], this indicates that these two ASI's are not completely independent from these variables.

Kim et al.[30] studied the relationship between several gait parameters (among others, stance duration, step duration and stride length) and the symmetry indices of these parameters in small and large dogs (<10 and >25 kg). In contrast to our findings in piglets, no differences in symmetry indices were detected between the two groups of dogs. Although Kim et al. did not assess the influence of the dog's weight on the ASI for step length, one might assume this variable did not differ between the two groups, since the ASI for stride length as well as the one for step duration did not differ between sound and lame dogs.

As far as we know, the positive correlation between velocity and the ASI for step duration has not been described before. This result is in contrast with previous findings by Oosterlinck et al.[13] and Meijer et al.[21] that did not find a significant influence of velocity on ASI's. Considering that the correlation found in this study were weak, one might question the relevance of this finding. However, it might be of some concern for the evaluation of gait in pigs, since it is impossible to maintain fixed speeds over several trials without disturbing natural gait in this species.

Since data from only 9 lame piglets were available for analysis, the left/right distinction of the ASI's was left out of consideration and further analysis was performed on the absolute values. Therefore, in the current study no discrimination was made between left and right sided lameness. This choice was supported by the findings of Lequang et al.[19], that did show significant differences in symmetry between sound dogs' front and hind limbs, for stance time, relative stance time (stance percentage), peak vertical pressure and amount of activated sensors. No differences on any of the tested variables were detected between left and right. In accordance Light et al reported a perfect symmetry in dogs between left and right but asymmetry between the front and hind limbs.[31]

Pressure mat variables

Footscan® analysis provides objective information on spatiotemporal patterns, forces, timing and symmetry in gait. Footscan® and pressure mat analysis is widely used to quantify these gait characteristics in many species, including humans[32] and several quadruped species[12-14,17,20,33]. Recently cut-off values of force related ASI's obtained from pressure mat analysis have been determined for young sound piglets followed between 5 and 10 weeks of age[21]. Until now, no data were available upon the six spatiotemporal ASI's obtained from pressure mat analysis in our study. Three of the six tested variables showed significantly higher ASI's in lame piglets than in controls, namely ASI stance duration, ASI stance percentage and ASI step duration. The ASI for step length did show a significant difference between the non-affected side of lame piglets and controls but only a trend towards significance for the difference between the controls and the affected side of lame piglets. The mean ASI stride length and stride duration did not differ between the two groups.

In contrast to the amount of studies on gait forces and pressures, little is known about these variables. A recent study compared 5 lameness detecting methods, among which pressure mat analysis, in breeding sows. No differences could be detected between lame, mildly lame and sound sows for stride length, stance duration and step duration[5]. In contrast, Karriker et al.[34] found a significantly lower stance duration in sows with induces claw joint lameness. Although not significant, it might be interesting to mention the slightly lower ASI for stride length for the effected side of lame piglets compared to the control in our present study. This contrasts with the five other variables, all showing higher ASI's in lame animals. This phenomenon has been described before in horses with forelimb lameness[35]. These animals showed an increase in standard deviation of stride length after local anaesthetic relieved them from their lameness associated pain. The author suggested that lameness associated pain would optimise compensation in movement and therefore less pain due to anaesthetics would lead to larger differences in stride length. Two other studies compare stride length and stride duration in lame and control cattle[36] and mice[37]. Mice with induces spinal court trauma showed a decrease in stride length as did cattle with sole ulcers for stride length as well as stride duration.

All four variables showed a higher mean ASI at the non-effected side compared to the affected side, although this difference only appeared to be significant for step length. This might be due to possible differences in coordination between contralateral limbs and ipsilateral limbs. However, little is still known about the regulation of coordination is.[38,39]

Replicability

As described in the results, the intra class correlations between the runs were very poor. This indicates a large variance between individuals. In this study two mean asymmetry indices were calculated from a total of 8 valid contact points. With this finding, it might be of interest to compare multiple asymmetry indices obtained within the same run. By using an average, it remains inconclusive weather the variation of ASI's only exists between runs or within runs as well. If the ASI's appear to differ a lot within a run, the ASI might not be a constant enough factor to use as a diagnostic value.

Future use: diagnostic tool

The aim of this study was to determine the method's capability to be used as a practical diagnostic tool for lameness. Currently, the majority of veterinarians diagnose lameness by visual observation. However although observations might be very accurate in trained observers, studies show a low sensitivity between different observers[10], even with standardized protocols[6].

This highlights the need for a new, practical, objective and fast diagnostic tool. In several species, among which pigs[33], the use of force parameters obtained by pressure mat analysis show promising results in detecting lameness. The variables considered here (stance duration, step duration, step length and stance percentage) do seem to discriminate effectively between lame and sound piglets. However, because of the use of absolute values of the average asymmetry indices this study remains inconclusive about the method's ability to discriminate between left and right sided lameness. Additionally, two proper contacts per limb, put down on the pressure mat in the right order are necessary to obtain an ASI. This would excluded piglets with irregular gaits or extreme lameness in which the affected limb is not or hardly challenged. Currently, data-analysis is a time-consuming process because of the lack of a program for automatic data collection for quadrupeds. Before the pressure mat is suited to be used in clinical situations, automatic selection, paw contact assignation and asymmetry indices should be included.

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