The Veterinary Journal 205 (2015) 38–43

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Pre-clinical and clinical walking kinematics in female breeding pigs with lameness: A nested case-control cohort study

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ARTICLE INFO

Article history:
Accepted 16 April 2015

Keywords:
Sow
Biomechanics
Motion analysis
Lameness
Prevention

ABSTRACT

Gait profiles were investigated in a cohort of female pigs experiencing a lameness period prevalence of 29% over 17 months. Gait alterations before and during visually diagnosed lameness were evaluated to identify the best quantitative clinical lameness indicators and early predictors for lameness. Pre-breeding gilts (n = 84) were recruited to the study over a period of 6 months, underwent motion capture every 5 weeks and, depending on their age at entry to the study, were followed for up to three successive gestations. Animals were subject to motion capture in each parity at 8 weeks of gestation and on the day of weaning (28 days postpartum). During kinematic motion capture, the pigs walked on the same concrete walkway and an array of infra-red cameras was used to collect three dimensional coordinate data of reflective skin markers attached to the head, trunk and limb anatomical landmarks.

Of 24 pigs diagnosed with lameness, 19 had preclinical gait records, whilst 18 had a motion capture while lame. Depending on availability, data from one or two preclinical motion capture 1–11 months prior to lameness and on the day of lameness were analysed. Lameness was best detected and evaluated using relative spatiotemporal gait parameters, especially vertical head displacement and asymmetric stride phase timing. Irregularity in the step-to-stride length ratio was elevated (deviation ≥0.03) in young pigs which presented lameness in later life (odds ratio 7.2–10.8).

Introduction

Lameness has an impact on the health, welfare and production economics of sow herds (Heinonen et al., 2013; Willgert et al., 2014). The reported prevalence of lameness among gilts and sows ranges from 5% to 20%, depending on the assessment method, production system and genotype (KilBride et al., 2009; Nalon et al., 2013). Lameness is a clinical sign defined by observable changes in gait (Weishaupt, 2008). Whilst degenerative joint disease and associated leg weakness are the predominant causes of lameness in growing pigs, secondary degenerative changes and infectious arthritis are the most common causes in sows (Dewey et al., 1993; Kirk et al., 2005). Group housing systems for breeding females appear to increase the prevalence of lameness (Spoolder et al., 2009). Claw lesions are widely observed in sows, but their presence does not sufficiently explain the level of lameness observed (Pluym et al., 2011; Grégoire et al., 2013).

Subjective gait scoring protocols are currently the only on-farm tool available for the quantification of lameness (Main et al., 2000; de Koning et al., 2012), but these have low repeatability (Petersen et al., 2004). Subtle lameness is difficult to detect and evaluate (D'Eath, 2012), and is costly and time-consuming to observe (Nalon et al., 2013), especially since there is a need to examine a substantial number of animals to obtain accurate estimates of the prevalence of lameness (Mullan et al., 2009).

Identification of biomechanical parameters of locomotion could provide an objective means of identifying animals with lameness (Sun et al., 2011; Karriker et al., 2013), improve our understanding of disease of the musculoskeletal system and enable detection of animals with otherwise unobservable abnormalities. Herds could benefit from the development and implementation of automated and continuous on-farm lameness monitoring systems (Keegan, 2007; Cornou et al., 2008).

The aims of this study were: (1) to determine characteristic movement changes in gilts and sows with clinical lameness based on an analytical biomechanical method, i.e. lameness detection, and (2) to determine whether gait characteristics in pre-breeding gilts could predict subsequent lameness, i.e. lameness prediction. It was hypothesised (1) that there would be similar changes in the kinematics of lame pigs, regardless of affected limb(s); (2) that simultaneous consideration of two or more quantitative gait variables could indicate the site of lameness, and (3) that early gait records of pigs that developed lameness at a later time point could be differentiated from control pigs that were consistently sound

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http://dx.doi.org/10.1016/j.tvjl.2015.04.022
1090-0233/

during the study period. It was assumed that the majority of the diagnosed lameness would be due to chronic and previously latent abnormalities and not due to injuries or infections in an otherwise healthy musculoskeletal system.

Materials and methods

Animals

All procedures on animals were undertaken in accordance with institute guidelines and UK animal welfare regulations (ERC project number 274, date of approval 17 May 2011). The experimental cohort consisted of 84 pre-breeding Large white × Landrace gilts from the Newcastle University pig unit. Gilts were recruited to the study from January 2011 to July 2012. At the time of entry to the study, the youngest batch of gilts weighed on average 39 ± 3.8 kg (mean ± standard deviation, SD) and the oldest weighed 146 ± 13 kg.

Data collection

Pigs were initially habituated to close human contact and learned to follow a human operator to obtain a small piece of apple as a reward when movement was regular, continuous and straight. Motion capture was initially applied to the same pigs every 5 weeks to build a database of gait development during growth from initial selection, typically at 40 kg bodyweight (BW) or 4 months of age, to the point of insemination, typically at 140 kg BW or 8 months of age. The median number of motion captures for pre-breeding gilts was 3 (range 1–5). Subsequently, each pig underwent motion capture in mid-gestation (typically at 8 weeks after insemination) and on the day of weaning (after 28 days of lactation) during each parity. The study was terminated in July 2013, at which point the oldest sows had weaned their third litter.

A kinematic reflective marker model was applied to the pigs over key anatomical landmarks and captured with a T20 six camera three-dimensional (3D) system (Vicon), providing full body kinematics of one body side at a time (Stavrakakis et al., 2014a, 2014b, 2014c).

Lameness was clinically diagnosed using a subjective scale adapted from Main et al. (2000) immediately after motion capture as follows: 0, normal; 1, stiffness; 2, reduced weight bearing; 3, minimal weight bearing; 4, limb not used while moving; 5, animal does not move. Animals with scores of 4 and 5 were not subjected to motion capture. The period prevalence of lameness was defined as the proportion of the total number of animals recorded with clinical lameness at any point during the 17 month study, whilst period incidence was defined as the number of separate clinical cases of lameness which occurred within the study period, with several animals counted repeatedly. Attempts were made to achieve a tentative diagnosis of the cause of lameness. Pressure tests including palpation of all joints in the affected limbs(s) were made, as well as an assessment of a number of leg weakness traits (Table 1). A general impression of hoof health, shape and size was also recorded.

Data processing

Of the 24 females showing clinical lameness (i.e. score ≥2 at any time point), 19 had preclinical motion capture records from the pre-breeding stage and 18 had a usable motion capture while lame. Of the others, three were already lame at the first pre-breeding motion capture and two had no usable early motion capture data.

To identify biomechanical indicators of clinical lameness in gilts and sows, the gait data of the 18 gilts or sows with lameness were grouped according to the site of lameness and compared with data from sound control pigs, matched to production stage and BW.

Table 1
Leg weakness traits adapted from Jørgensen and Andersen (2000).

Characteristic	Deficiency	Description
Alignment of front and hind limbs	Buck-kneed	Front limbs buckling forward
	Sickle-hocked	Excessive bending of hind limbs at hock
	Post-legged	Excessive straightness
	Splay-footed	Toes/limbs turned out
	Pigeon-toed	Toes/limbs turned in
	Varus	O-shaped coronal profile of front or hind pair
	Valgus	X-shaped coronal profile of front or hind pair
Spine	Kyphosis	Humped back
	Lordosis	Broken back
Hooves	Weak pastern	Pastern touching ground
	Upright pastern	Pastern angle too steep
	Unevenness	Uneven claws of hoof

To identify predictors of lameness, early gait records of pre-breeding gilts which subsequently developed lameness (preclinical pigs; $n = 19$) were separated into two BW groups, generating two separate data sets, i.e. 63 kg median BW gilts (range 45–77 kg; $n = 13$) and 97 kg median BW gilts (range 84–123 kg; $n = 11$). This approach enabled the recruitment of at least 10 subjects per BW group. Although most pigs developing lameness appeared only once in a particular BW category, five pigs appeared in both BW groups due to a second pre-breeding record prior to lameness. Gait data from sound control pigs matched by BW, but with no perceived gait abnormality throughout the study period, were used for comparison.

Coordinate data were exported from motion capture software (Vicon Nexus, Version 1.7.1) and imported into Matlab (Mathworks, Version R2010b). Data were processed using a custom written programme for stride event detection and gait parameter calculation (Stavrakakis et al., 2014b).

Data analysis

Angular, temporal and spatial kinematics were analysed for differences across groups. Within subject means were created for every gait parameter and capture, and included left and right body sides (i.e. total session means). Front and hind limb gait parameters were analysed separately, except for stride lengths. To assess asymmetry, differences between left and right side measures, or the within session SD, were considered in addition to the mean gait parameter.

To exclude factors that might cause differences in gait other than those under investigation, all compared groups (Tables 2–6; see Appendix: Supplementary material) were checked for absence of differences in size (BW, limb length) and walking speed. The data were not normally distributed and therefore Mann–Whitney tests were used to compare cases and their matching control groups (Minitab version 16).

If gait is perfectly symmetrical, step length is half the stride length, so that the step-to-stride length ratio is 0.5. Thus, deviation from perfect symmetry, using a value for the step-to-stride length ratio of 0.03 as a threshold deviation, was determined for individual pigs. These were then classified as having either normal or abnormal gait, and either future or no future lameness.

Results

Lameness

Bodyweight, limb length and walking speed were not significantly different between lame pigs and their matched controls. Over the 17 months, there were 33 cases of lameness in 24/84 (29%) animals. Lameness affected 14 pre-breeding gilts, six gilts in mid-pregnancy, one gilt during lactation and three gilts in their second gestation. Over the course of the study, two gilts were euthanased due to severe bilateral hind limb lameness and 17 were culled due to reproductive failure. Lameness severity scores were similar between pre-breeding animals (mean ± SD lameness score 2.6 ± 0.74) and breeding animals (2.4 ± 0.52).

Clinical diagnosis of the affected limb(s) was possible in all but five cases, where either multiple limbs were involved or the site of lameness could not be determined. In general, lameness did not appear to originate from the claws and there were no obvious clinical signs of infection and inflammation. The repeated occurrence of lameness in some animals and the relatively high prevalence among the maturing gilts supports the idea that clinical lameness was a result of chronic, degenerative joint abnormalities.

Angular kinematics during clinical lameness

Table 2 shows joint flexion differences detected in pigs with lameness compared to sound control pigs. Stifle flexion was increased in pregnant gilts with lameness of uncertain origin (median difference +4°; $P = 0.02$), but was not significantly increased in pre-breeding gilts with hind limb lameness ($P = 0.06$). There was no significant difference in joint flexion between left and right stifles of pregnant gilts with lameness of uncertain origin ($P = 0.08$).

Temporal kinematics during clinical lameness

In general, the differences between left and right hoof stance times, swing times and duty factors within a pair of limbs were greater for lame pigs than for controls (Table 3). Pigs lame in a front