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Using centers of pressure tracks of sows walking on a large force platform in farm conditions for locomotion classification

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ABSTRACT

This study examines the feasibility of using a 3.0-m-long, 1.5-m-wide force platform to group into clusters the centers of the ground pressure tracks of sows walking on it. The clusters were created according to variables related to the symmetry and cadence of the sows' locomotion, and permitted an evaluation of its soundness in each cluster. Observations were made in a swine-breeding farm that followed standard swine production practices. In the farm, the sows were moved when farrowing from the gestation stalls to the farrowing crates, and were then returned to the service stalls. On these occasions, as recorded over the course of six months, each sow separately passed through a corridor connecting the two rooms, which is where the force platform was placed. The sows were not trained for this task. Signals were separately extracted from four load cells located under the platform, and were processed to obtain the center of pressure (CoP) and the vertical ground reaction force (F) of each sow as it walked on the platform (322 CoP tracks). The trajectory of each sow was derived from the generated CoP track. A gait cycle was considered complete when the CoP track oscillated (swayed) once in the plane of transversal of the sow's trajectory. In each gait cycle, the following variables were calculated: mean velocity, normalized impulse balance per gait cycle, number of relevant peaks of F per gait cycle, and peak ratio obtained from the autocorrelation function of F. Using these variables, all CoP tracks were classified into three clusters ($p < 0.05$). The relationships among the variables in each cluster allowed for distinction among the CoP tracks in terms of the soundness of locomotion. No significant differences in the measured variables were observed between the CoP tracks of primiparous and multiparous sows, whereas sows entering the farrowing crates were found to walk more slowly ($p < 0.05$) and with less balance ($p = 0.063$) than when leaving it. Considering *intraclass correlation coefficient* of the variables per CoP track as an indicator of locomotive soundness, the cluster of the fastest and most balanced CoP tracks yielded significantly more reliable *impulse balance* ($p < 0.05$) responses than did the other clusters. More reliable *impulse balance* was also observed in CoP tracks made by multiparous sows than by primiparous ones, and by the sows leaving than those entering the farrowing crates ($p < 0.05$).

1. Introduction

Approximately 50% of sows on commercial farms in Spain (BDPorc, 2015), France (IFIP, 2014), and other European countries are culled annually. Although nearly 10% of the culled sows are lame (Engblom et al., 2007), Kirk et al. (2005, 2008) observed that approximately 90% suffered from arthrosis as secondary diagnosis. Therefore, many instances of subclinical lameness that affect the motion of sows may not be detected on the farm because of poor care and the difficulties associated in obtaining a reliable visual observation of such a mechanical dysfunction due to intra- and inter-observer variability. Several gait scoring techniques have been proposed as solutions, but their results are subject to the expertise, inter-observer variability, and observational drift (Main et al., 2000; D'Eath, 2012).

Instrumental diagnosis enables objective classification of locomotion. Kinetic models have been developed to extract the main parameters required for such diagnoses, such as the ground reaction force, particularly its vertical component (hereafter, F), and the center of pressure position (CoP).

For humans, a CoP track on a force platform provides an indirect measurement of postural sway for slow movements. The swaying pattern—analyzed using such parameters as swaying area, swaying

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amplitude, CoP velocity, CoP acceleration, and the main frequency of the CoP track—has been studied as a possible means of detecting imbalance in patients with cerebral palsy (Kim et al., 2009). Furthermore, gait symmetry has been studied as an aspect of a normal gait (Sadeghi et al., 2000). CoP and ground vertical force data obtained from a force platform have both been reported as containing a component of neurophysiological response in postural control (Clark and Riley, 2007); this is particularly evident in cases of displacement, rendering reliable gait classification challenging. The single-session reliability of gait variables has traditionally been evaluated using the intraclass correlation coefficient, and the number of gait cycles needed to obtain an intraclass correlation coefficient of >0.9 has been estimated (Redekop et al., 2008; Hollman et al., 2010).

In equine studies, lameness has been studied using numerous techniques, such as force and pressure platforms. Oosterlinck et al. (2010) compared them and concluded that for the accurate measurement of forces, the force platform was the best option. Methodologically interesting were the kinetic studies undertaken by Weishaupt et al. (2004), in which a force plate was set up under a rubber treadmill. Symmetry was evaluated by analyzing the force peaks, and the impulse balance between the left and right sides and the diagonal limb pairs. They evaluated trot regularity or cadence by calculating the correlation coefficients of the right and left accelerometer signals registered on the sternum and sacrum once the signals had been processed using the autocorrelation function. Each step was positionable because of the use of a grid of 18 load cells set up under the platform.

Similar objective methods for assessing locomotion have been applied to the dairy farm sector. They can offer accurate and reliable data, but limited pathological identification had thus far been obtained (Flower and Weary, 2009). Rajkondawar et al. (2002) implemented two parallel force plates that detected lame cows by evaluating symmetry among such variables as normalized peak ground reaction force and impulse, and cadence in stance time. With a similar device, Skjøth et al. (2013) were able to locate cow footfalls by clustering CoP points over space and time. Maertens et al. (2011) used a pressure-sensitive walkway and, using cows that had previously been classified by gait scoring, observed differences in symmetry and cadence. Their algorithm to delete anomalous data acquisition due to cows stopping, running, or slipping on the pressure-sensitive mat was remarkable.

Lameness in sows was detected immediately by evaluating asymmetries in maximum pressure, stride length, stance time, activated sensor count, and stride time per foot while walking them on a pressure-sensitive mat (Karriker et al., 2013; Mohling et al., 2014).

Floor conditions can influence pig locomotion (Thorup et al., 2007; von Wachenfelt et al., 2010); thus, kinetic or kinematic data should be comparatively assessed among animals in similar conditions.

As mentioned above, several devices are available for evaluating the soundness of locomotion, but most are considered unsuitable for livestock management. For instance, treadmills are unfeasible because of the need for animal training and the lack of time it affords to separately care for farm animals. Matrix-based pressure-sensing systems can track each step and evaluate relative pressure at any point, but are expensive, have short working lives, and they are associated with high levels of hysteresis and inaccuracies in force estimation (Ashruf, 2002). Moreover, these pressure-sensitive mats generate an enormous amount of data that farmers would need to interpret, making these devices less practical for farm conditions. Although force platforms cannot precisely locate individual steps because of the limited number of load cells, even the CoP track of an entire animal can offer information pertaining to its locomotion. However, this has not been subjected to experiments with livestock.

This study explores the feasibility of using a large force platform (3.0 m long, 1.5 m wide) to cluster into groups the centers of the pressure tracks of sows walking on it to assess the soundness of their locomotion. Since farmers must make decisions relating to individual animals (such as when to cull), the reliability of the proposed method is also discussed. Moreover, the reliability of the locomotion variables is considered as a possible consequence of sound sow locomotion.

2. Materials

Observations were conducted on a landrace-breeding farm (approximately 400 productive sows). Farm management was not affected by the observations, and the sows had been reared by farmers. Therefore, they were sampled not according to specific criteria but the ongoing management. The sows had been separately reared in stalls with partially slatted floors and observing the swine welfare standards of that moment. On average, the observed sows (n = 263 sows) were third parity (82 primiparous sows) and had three-week lactation periods; the mean values of their live weights and backfat thickness at P2 were 2.45 kN (15% CV) and 20.7 mm (16% CV) before farrowing and 1.95 kN (18% CV) and 17.1 mm (17% CV) at weaning, respectively.

In managing the farm, some sows were moved a week before farrowing from the gestation stalls to the farrowing crates, and others were returned to the service stalls after weaning. On these occasions, the sows crossed the force platform only once without being trained to do it. Over a six-month period (weekly in two summer periods of three months each), without disturbing routine work in the farm, the sows were separately walked through a corridor, where the force platform was placed, as they usually did in the farm. However, some of them (four sows) died before they could go to the farrowing crates; others (11 sows) going to the farrowing crates were not recorded due to acquisition problems, and still others (22 sows) died or were culled during the lactation period, and hence there were no records of them leaving the farrowing crates. Consequently, 485 records of sows on the force platform were available.

The force platform was as wide as the corridor; therefore, sow locomotion was unrestricted (Fig. 1). The platform's length was designed to capture three complete gaits, and ramps were installed to induce a natural pace. Usually, they needed encouragement to walk from the farmer walking behind them. In this sense, records were excluded from the analysis not on the basis of locomotion quality, but when sows stopped moving on the platform, and prevented the recording of at least one gait cycle at a natural pace. The situation was verified by means of video recordings. Thus, excluding such tracks (163 sow tracks, 34%), 322 sow tracks were analyzed, and only 98 pairs (196 sow tracks) were available from sows that both came in and out of the farrowing crate for the same parity; there was at least one CoP track per sow from 224 sows.

The force platform was a 1.5-m-wide and 3.0-m-long structure simply supported on 3.0-m-long steel billets. The transverse beams were edge-supported by compression load cells CCM-250 (AEP-Transducers®, Modena, Italy). The load was therefore statically distributed on only four load cells and could support up to 2.5 kN at the platform vertices. Certain special design considerations served to protect the system from the harsh farm environment (e.g., humidity, rats, and mechanical impacts). The force platform was calibrated statically such that it was adequately rigid to simultaneously carry the forces to the load cells.

The force platform was triggered manually. Signals were separately received from each load cell at a sampling rate of 200 S/s by using a PCMCIA card NI-6024 (National Instrument®, Austin, USA). The device was powered using 12-V batteries to ensure mea-