Defining resilient pigs after a Porcine Reproductive and Respiratory Syndrome Virus (PRRSV) challenge using activity and feeding data from accelerometers

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Abstract

Porcine reproductive and respiratory syndrome (PRRS) is an infectious viral disease in pigs. PRRS causes reproductive failure in sows and respiratory infections in growing pigs. To improve pig health and minimise economic losses, resilient pigs are preferred within the herd. Resilient pigs still become infected, yet are able to recover following infection, showing less variation in activity and feeding. In this study, 232 commercial crossbred pigs were equipped with individual accelerometer ear tags to monitor the number of active, feeding, and hyperactive events per individual per hour. At eight weeks of age, pigs were inoculated with PRRS virus 1-7-4. Data from accelerometers were collected 23 days prior to challenge and 42 days post-infection (dpi). Expected levels of activity, feeding, and hyperactivity were estimated by regressing behavioural traits on observed datapoints prior to challenge. This regression line was extended to 42 dpi. Then, deviations from the regression line were quantified as Root Mean Square Error (RMSE) for each individual during the following time periods: pre-challenge, 0–13 dpi, and 13–42 dpi. All traits decreased and RMSE increased post-challenge. These results are consistant with clinical signs of PRRS, including lethargy and loss of appetite. In addition, association of these traits with survival was also investigated. RMSE prior to PRRS-infection was not predictive of survival after infection. However, RMSE of feeding and activity during the peak challenge period (0–13 dpi) was predictive of survival, where pigs with less deviation in behaviour were more resilient to the PRRS challenge.

Keywords: PRRS, accelerometers, RMSE, resilience, behaviour, pig

Introduction

Porcine reproductive and respiratory syndrome (PRRS) is an infectious viral disease and is present in almost every major pork producing country (Dea *et al.*, 2000). It emerged in North America around 1989 (Collins *et al.*, 1991) and in Europe three years later (Wensvoort *et al.*, 1991). Mortality rates up to 20% due to North American strains and up to 10% due to European strains has been observed (Lunney *et al.,* 2010). As its name implies, PRRS results in two main pathologies: reproductive failure and respiratory disease. Reproductive failure occurs in pregnant sows and results in abortions, mummified piglets, and weak live born piglets. Growing pigs infected with PRRS may suffer from high fever, loss of appetite, and become lethargic or less active. This could also lead to reduced growth and productivity. The course of the clinical signs is on average two weeks. Besides the impairment of pig welfare, PRRS causes severe economic losses to the farmer, estimated at $74.16 per litter and $7.67 per finisher (Neumann *et al.*, 2005). To improve pig health and curtail economic losses, resilient pigs are preferred within the herd. Resilient pigs are able to recover relatively quickly, and actively lower the viral load within the herd in spite of being infected (Berghof *et al.*, 2018).

Implementing selection for pigs with increased resilience to PRRSV-infection would be desirable for a breeding program. However, resilient breeding candidates are difficult to identify. One approach that can be used to quantify resilience is to compare normal expectations to behaviour following a disease challenge. Each animal has a unique pattern of behaviour, and deviations from this pattern following disease challenge, might provide insight regarding the impact of disease and/or recovery post-infection. Using human observations to measure behaviour is subjective and labour intensive. Precision phenotyping tools, such as wearbale accelerometers, which are capable of quantifying behaviour automatically are, therefore, an attractive alternative. An accelerometer measures acceleration in three dimensions. A machine learning model is then used to recognise activity, feeding and hyperactivity in the acceleration data. It has been reported that deviations from normal expectations in the activities due to disease can be used as a measure of resilience. Putz *et al.* (2018) quantified resilience using Root Mean Square Error (RMSE) of feed intake and feeding duration. It was shown that RMSE can be used as an indicator trait for resilience and quantifies return to baseline. Therefore, the objective of this study is to evaluate the usefulness of variation in activity, feeding and hyperactivity measured through accelerometers to define resilience to PRRS-infection.

Material and methods

Animals and housing

A total of 2186 commercial crossbred pigs were farrowed at a commercial sow farm and shipped to a commercial research facility at weaning. Upon arrival, pigs were balanced by sex with 27 pigs housed per pen in 81 total pens. All pigs were vaccinated per label with a PRRSV modified live virus vaccine (IngelVac ATP, Boehringer Ingelheim) upon entry and experimentally inoculated with PRRS virus variant 1-7-4 four weeks later at a total dose of 1x105 TCID50 via the IM route. Pigs received mass treatments at 21 and 26 dpi and individual treatments as needed from 21 dpi onward.

Data collection

A subset of 232 pigs was equipped with individual accelerometer ear tags from Remote Insights. Acceleration data were recorded 23 days prior to infection and 42 days post-infection (dpi). Accelerometers detected acceleration in three dimensions. A machine learning model was trained from video observations to recognise activity and chewing behaviour. Hyperactivity was calculated directly from the raw acceleration data. A hyperactive event was recorded when the acceleration surpassed a defined threshold. Activity, feeding, and hyperactivity were averaged per day and expressed in minutes per hour.

Statistical analyses

RMSE was computed for each pig by calculating the within animal variation for activity, feeding, and hyperactivity from the linear regression using R (Figure 1). Activity, feeding, or hyperactivity was regressed using only observations pre-challenge (-23 – 0 dpi). This regression line was extended to 42 dpi, obtaining expected behaviour over time without the interruption of a challenge. RMSE was calculated for each trait using the observed values from the accelerometers, and expected values from regression. The following formula was used to calculate RMSE for each period:

$$RMSE = \sqrt{\frac{\sum(Observed - Expected)^2}{Number\ of\ observations}} \qquad (1)$$

Where *Observed* is the observed value from the accelerometer, *Expected* the expected value based on the linear regression. RMSE was calculated pre-challenge (-23 – 0 dpi), early post-

infection (0–13 dpi) and late post-infection (13–42 dpi). Data were analysed using a linear mixed model in ASReml. Sex was fitted as a fixed effect and pen was fitted as a random effect.
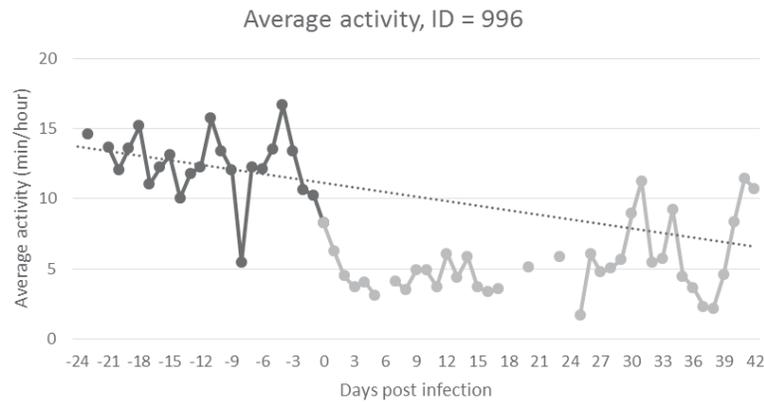
Figure 1. Example of activity data per day in minutes per hour generated by the accelerometer. The dots are observed activity, where the darker shade of grey is used for the linear regression. The solid line represents the time of PRRS infection and the dashed line the linear regression of expected activity and arrows show examples of deviations from expectations

Results and discussion

Behaviour

Table 1 shows average activity, feeding, and hyperactivity for each period in minutes per hour. The pigs were less active and spent less time feeding post-challenge compared to pre-challenge. Hyperactivity was not affected by PRRS-infection to the same extent as activity and feeding. Activity, feeding, and hyperactivity did not return to baseline post-challenge. Nordgreen *et al.* (2018) observed similar behaviour, where individuals were less active and had less appetite post-challenge than pre-challenge. These results show that accelerometer data reflect the expected change in behaviour due to PRRS-infection.

Table 1. Difference in average activity, feeding, and hyperactivity in minutes per hour for different periods for pigs who were either dead or alive at the end of the challenge

Average	Activity (min/h)		Feeding (min/h)		Hyperactivity (min/h)	
	Alive	Dead	Alive	Dead	Alive	Dead
Pre-challenge	12.53	12.34	6.33	6.08	0.36	0.43
Early post-challenge	8.05	5.85	3.89	2.19	0.30	0.29
Late post-challenge	7.05	5.22	4.03	1.91	0.27	0.30

A linear regression was fitted on data pre-challenge to estimate the expected behavioural pattern of a pig over time. As anticipated, pigs deviated from this expected patten following challenge, reflected by increased RMSE values for each trait: activity, feeding, and hyperactivity. Of these traits, activity had the highest RMSE, regardless of time period (Figure 2). Of the time periods, the late post-challenge period (13–42 dpi) had the highest RMSE, regardless of trait. Based on Table 1 we can conclude that the increase in RMSE is due to a decrease in activity, feeding, and hyperactivity following disease challenge, which is consistent with clinical signs of PRRS-infection, including lethargy and loss of appetite.
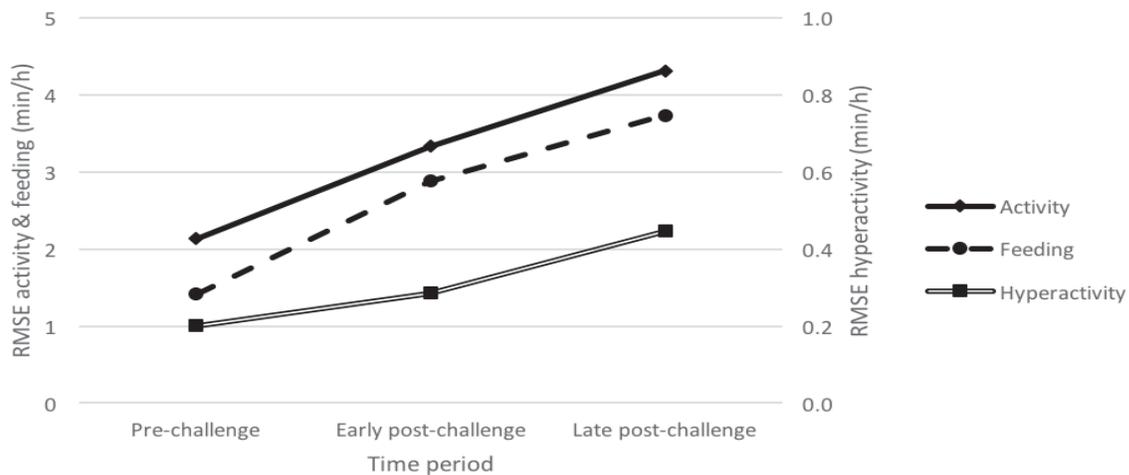
Figure 2. Average RMSE for activity, feeding, and hyperactivity for each period

Survival

Resilience to PRRS-infection was also assessed using survival data. Compared to pigs that died following infection, pigs that survived had lower RMSE for activity and feeding from 0–13 dpi, and lower RMSE for activity and hyperactivity from 13–42 dpi (Table 2). These results suggest that it is possible to identify pigs that will survive the challenge based on RMSE for activity and feeding shortly after challenge. Although it would be more desirable to identify resilient pigs without the need of a PRRS-infection, the lack of a significant effect of RMSE pre-challenge on survival suggests that variation in behaviour in the absence of disease did not truly reflect the chances of survival following infection.

Table 2. Solutions of RMSE early and late post-challenge of activity, feeding, and hyperactivity of animals that survived PRRS-infection compared to deceased pigs. NS = non-significant

Solution RMSE	Activity	Feeding	Hyperactivity
Early post-challenge	-1.48 ± 0.35	-1.57 ± 0.36	NS
Late post-challenge	-2.41 ± 0.81	NS	-0.15 ± 0.07

Conclusions

Results from this study suggest that accelerometer data can be used to characterise the behavioural patterns of pigs. Activity, feeding, and hyperactivity decreased post-challenge, which is consistent with the classical signs of PRRS-infection. Prolonged infection was observed, since neither activity, feeding, nor hyperactivity returned to baseline by 42 dpi, which suggests that pigs had not yet recovered from the infection by this timepoint. RMSE was used to quantify the deviation of a pig's observed behaviour post-infection from its expected behaviour. Results showed that RMSE of activity, feeding, and hyperactivity prior to PRRS-infection were not predictive of survival. However, RMSE during the early post-infection phase (0–13 dpi) was predictive of survival, where pigs with lower RMSE for activity and feeding during this phase were more resilient to PRRS challenge.

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