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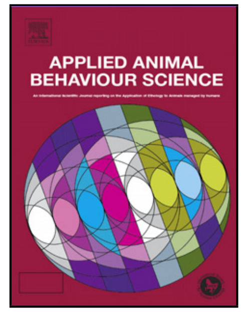

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Tail posture predicts tail biting outbreaks at pen level in weaner pigs

Short title: Tail posture predicts tail biting in pigs

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Highlights

- Changes in tail posture can predict a tail biting outbreak at pen level
- Percentage of hanging tails in pens close to an outbreak was almost doubled
- A correlation between number of tail damages and lowered tails were identified
- No changes in activity was identified prior to a tail biting outbreak

Abstract

Detecting a tail biting outbreak early is essential to reduce the risk of pigs getting severe tail damage. A few previous studies suggest that tail posture and behavioural differences can predict an upcoming outbreak. The aim of the present study was therefore to investigate if differences in tail posture and behaviour could be detected at pen level between upcoming tail biting pens (T-pens) and control pens (C-pens). The study included 2301 undocked weaner pigs in 74 pens (mean 31.1 pigs/ pen; SD 1.5). Tails were scored three times weekly (wound freshness, wound severity and tail length) between 07:00h-14:00h from weaning until a tail biting outbreak. An outbreak (day 0) occurred when at least four pigs had a tail damage, regardless of wound freshness. On average 7.6 (SD 4.3) pigs had a damaged tail (scratches + wound) in T-pens on day 0. Tail posture and behaviour (activity, eating, explorative, pen mate and tail directed behaviour) were recorded in T-pens and in matched C-pens using scan sampling every half hour between 0800-1100h and 1700-2000h on day -3, -2 and -1 prior to the tail biting outbreak in T-pens. Further, to investigate if changes in tail posture could be a measure for use under commercial conditions, tail posture was recorded by direct observation from outside the pen. The live observations were carried out just before tail scoring on each observation day until the outbreak. The video results showed more hanging/tucked tails in T-pens than in C-pens on each recording day ($P<0.001$). In T-pens more tails were hanging on day -1 (33.2%) than on day -2 (24.8%) and day -3 (23.1%). Further, the number of tail damaged pigs on day 0 was correlated with tail posture on day -1, with more tails hanging in pens with 6-8 and >8 tail damaged pigs than in pens with 4-5 tail damaged pigs ($P<0.001$). Live observations of tail posture in T-pens also showed a higher prevalence of hanging tails on day 0 (30.0%; $P<0.05$) than on day -3/-2 (17.2%), -5/-4 (15.4%) and -7/-6 (13.0%). No differences in any of the recorded behaviours were observed between T-pens and C-pens. In conclusion, lowered tails seem to be a promising and practical measure to detect damaging tail biting behaviour on pen level even when using live observations. However, there were no changes in activity, eating, exploration or tail-directed behaviours prior to a tail biting outbreak.

Keywords: pigs, tail posture, behavioural change, tail biting, tail damage

1. Introduction

Damage to pigs' tails due to tail biting has been observed in many different housing systems (Taylor *et al.*, 2010, D'Eath *et al.*, 2014). Today most pigs housed under conventional conditions are tail docked (EFSA, 2007), and research shows that tail docking reduces the prevalence of tail damage (Di Martino *et al.*, 2015, Lahrmann *et al.*, 2017). However, tail docking itself raises welfare and ethical concerns, and the European Commission recommends that pig producers reduce the need for tail docking by reducing the risk factors associated with tail biting and changing their management measures (EC, 2016).

If more pigs are to be housed with intact tails, it is essential that severe tail biting is prevented as discussed by D'Eath *et al.* (2016). Alongside reducing risk factors, a valuable approach to avoid severe tail biting outbreaks, is to detect and stop damaging tail biting behaviour in its very early stages (Schrøder-Petersen and Simonsen, 2001, D'Eath *et al.*, 2014).

A review by Larsen *et al.* (2016) described a few experiments investigating whether behavioural changes can predict a tail biting outbreak. These experiments identified that changes in tail posture and activity level could be indicators of a future tail biting outbreak (Zonderland *et al.*, 2009, Ursinus *et al.*, 2014). In one study, pigs with their tails between their legs had a higher risk of having a tail wound 2-3 days later (Zonderland *et al.*, 2009), and Ursinus *et al.* (2014) observed higher activity levels prior to a tail biting outbreak. These observations are supported by another small study with six tail biting pens, also suggesting that changes in tail posture and activity level might predict a tail biting outbreak (Statham *et al.*, 2009).

So far only a few and minor studies have suggested that changes in behaviour occur prior to a tail biting outbreak either on pig or pen level. If changes in behaviour and tail posture are to be used in a commercial setting as an early warning sign of a tail biting outbreak, it is essential that these can be recognized on pen level. On commercial farms tail biting outbreaks are handled on pen level and individual differences between pigs in a pen will generally not be detected. If changes in behaviour can predict a tail biting outbreak in the early stages at the pen level, pig producers could use this measure in their daily management inspections to identify at risk pens and take steps to reduce tail biting behaviour. In addition, if certain behaviours or tail postures can predict a tail biting outbreak, this opens up the possibility to predict future tail biting outbreaks automatically by the use of sensor or camera technology (Larsen *et al.*, 2016).

The aim of the present study was to investigate whether differences in tail posture and behaviour could be identified at the pen level between pens close to a tail biting outbreak and pens at least seven days away from an outbreak. The study was conducted at a commercial herd with undocked weaner pigs.

2. Material and methods

2.1 Ethical consideration

This experiment was conducted in accordance with the guidelines of the Danish Ministry of Justice, Act No. 382 (June 10,1987) and Acts 333 (May 19,1990), 726 (September 9,1993) and 1,016 (December 12, 2001) with respect to animal experimentation and care of animals under study.

2.2 Animals and housing

The study was carried out at a commercial Danish farm from November 2015 to February 2016. The subjects were 2,301 undocked DanAvl crossbred ((Landrace x Large White) x Duroc) weaner pigs (7-30 kg) from four different farrowing batches with 55-60 litters per batch and 555-623 pigs per batch. Pigs were born in a loose house farrowing system (for pen design details, see Pedersen *et al.* (2015)). On day 3 or 4 after birth all the piglets were given iron injections (Uniferon, Pharmacosmos, Holbæk, Denmark), their teeth were ground and male piglets were surgically castrated, (with the use of a short-term analgesia). From approximately 14 days of age piglets were offered solid creep feed on the floor. Two days prior to weaning, pigs were ear tagged and their sexes recorded. At weaning, pigs were 27.7 (SD 2.8) days old and weighed 5.8 (SD 1.5) kg. At this point they were transported to a weaner facility close to the sow unit.

At weaning, pigs were sorted by size within batch and allocated to new pens with 31.1(SD 1.5) pigs/pen. Recording of gender was missed for some pigs (2.1%). Gender distribution was 49.9% (SD 9.4) castrated males and 48.0% (SD 9.2) gilts per pen. The four experimental rooms consisted of 26 or 30 pens and 18 or 20 of these pens were included in the experiment in each batch. In total 74 pens were included in the study. Pens measured

4.85 × 2.18 m (length × width*)* with 7.1m^2 solid floor and 3.5m^2 cast iron slatted floor. Above the solid floor in the lying area a 2.16 m^2 adjustable covering was placed. Two adjacent pens shared a dry feed dispenser with two nipple drinkers, one placed in each side of the feed dispenser (MaxiMat, Skiold A/S, Sæby, Denmark). *In addition, a separate water supply (drinking bowl) was placed next to the feed dispenser towards the slatted floor.* Each pen was equipped with two wooden blocks hanging from a chain, not touching the floor. Pens were daily provided with approximately 350 g of finely chopped straw (Easy Strø, Dansk Dyrestimuli, Nykøbing Mors, Denmark) on the solid floor. Artificial lighting was turned on from 0600 h to 2200 h.

The ventilation system was based on negative pressure air flow from wall air inlets in one side of the building (SKOV A/S, Glyngøre, Denmark). At pigs' arrival, the room temperature was 24°C and it was gradually lowered to 19°C on day 42. Thermostatically controlled floor heating pipes were placed inside the floor in the lying area giving a floor temperature of 30°C at the start of the study. The floor heating was turned off on day 14.

Pigs were fed three different commercial compound diets (*ad libitum* access) from 7-30 kg based on wheat, barley, soy protein, fish meal (the last ingredient only from 10-15 kg body weight), minerals and vitamins. The diets were formulated to fulfil the nutritive requirements of pigs at this age and genotype. Transition between feed compounds was done gradually over a 7 or 14 days period – depending on the age of the pigs. The age of onset of a diet transition depended on the average body weight in the pen. The experiment continued until a tail biting outbreak occurred in a pen or until the pigs were moved to the finisher barn 6.5 week after weaning.

Pigs' health was monitored once daily in the morning by the stock person, and pigs with clinical signs of disease were treated with antibiotics. Unthrifty animals and pigs with severe tail lesions (more than half the tail missing or swelling as sign of infection) were moved to hospital pens.

If a tail biting outbreak occurred (see definition in 2.3 below) new enrichment materials were added to the pens, and the biter/biters were removed from the pen if they could be identified. The pen left the study at this point, and could not re-enter the study for use as a control pen even though tail wounds had healed. Tail wound healing of tail bitten pigs was followed closely to ensure that damaging tail biting did not continue.

2.3 Tail scoring and tail posture

Of the total number of experimental animals 2,259 pigs were tail scored in the farrowing stable and these pigs originated from 222 litters. From right after weaning, tail posture up (curly), down (hanging) or tucked (down and tucked into the body) and tail damage were scored three times weekly (Monday, Wednesday and Friday) until a tail biting outbreak occurred. After a tail biting outbreak, tails were scored once weekly until the end of the study (data not shown). To avoid affecting the tail posture, tail posture was scored from outside the pen before the observer entered each pen to score tail damages. Tail damage was assessed and scored using the scoring system described in Table 1.

Table 1 about here

2.4 Tail biting outbreak

A tail biting outbreak occurred when at least four pigs in a pen (~ 13% of the pigs) had a tail damage score of at least a wound. The day of the tail biting outbreak was determined based on the three weekly tail scorings. The daily caretaker did not record any tail biting outbreaks during daily management routines between tail scoring days. We use a numbering convention throughout this paper such that the day of the outbreak is day 0, and the days prior to the outbreak are -1, -2, -3 and so on. Tail biting outbreaks occurred in 70 pens, leaving only four pens without an outbreak in the entire study period (6.5 week).

2.5 Video recordings

An overhead video camera (Dahua 2MP HD IR Dome, Dahua, Haarlemmermeer, Netherlands) was placed above all pens timed to record from 0700 to 2100h from weaning until a tail biting outbreak. Due to the poor quality of the video recordings, the first batch (18 pens) had to be excluded from the video material leaving 56 pens for further analysis.

2.6 Pilot study

To determine the sampling method for the main study, a pilot study was conducted using videos recordings from 10 pens with tail biting outbreaks. Scan sampling of pig behaviour and tail posture (according to the ethogram in Table 2) were recorded on day -13, -10, -7, -4, -3, -2 and -1 prior to the outbreak (day 0) every half hour from 0700h to 2100h to determine if any changes in activity and tail posture could be determined and when the changes could be expected. Visual inspection of pilot study results suggested a change in activity and tail posture within the last three days prior to an outbreak, but not before this (data not shown). Further, these pilot study results showed high activity levels during the morning hours (0800-1100h) and late afternoon (1700-2000h; data not shown).

2.7 Behavioural recordings

Behaviour was recorded in pens which would go on to have tail biting in future (T-pens) and, based on pilot observations, pens at least seven days away from an outbreak were used as non-tail biting control pens (C-pens). Based on pilot study observations, it was decided to record pigs' behaviour and tail posture in T-pens and C-pens on day -3, -2 and -1 prior to an outbreak in T- pens to look for changes that could act as early warning of tail biting. Once every half hour pigs' behaviour was recorded using instantaneous scan sampling during the periods of high activity from 0800-1100h and 1700-2000h identified in pilot observations. The ethogram is presented in Table 2.

Table 2 around here

A tail biting outbreak occurred in 50 of the 56 pens included in the video study. To compare behavioural differences between groups, T-pens and C-pens were randomly paired within batch. Pigs in paired pens originating from the same farrowing batch were analysed on the same dates and were housed in the same room in the weaning period. A pen could feature as both a T-pen and a C-pen depending on the onset of the tail biting outbreak in the pen and the outcome of the random pairing. In order for a pen to be in the pool of available control pens, the pen had to be at least seven days away from a future tail biting outbreak. Based on the random pairing 24 different pens were drawn as C-pens. Therefore, on average a C-pen was paired twice with a T-pen ranging from one to seven pairings per C-pen within batch. If the same pen was picked as a control pen to pens with a tail biting outbreak on the same day, the control pen data only entered the statistical analysis once.

2.7 Statistical analysis

Statistical analyses were performed using SAS Enterprise Guide 7.1 (SAS Institute Inc., Cary, NC, USA) with significance level of $P<0.05$ and tendency level at $P<0.10$. Pen was the experimental unit in statistical analyses of behaviour and tail posture.

2.7.1 Video data

The percentage of tails down (sum of hanging and tucked tails), pigs at feed dispenser (sum of all behaviours recorded at the feed dispenser; Table 2), pigs performing explorative behaviour (sum of: nose enrichment + nose solid floor + nose slatted floor; Table 2), pigs performing pen-mate directed behaviour and tail directed behaviour (sum of: tail-in-mouth and nose tail region; Table 2) were calculated as the percentage of standing pigs at each scan. Data on pigs at the drinking bowl were not analysed due to low prevalence. The percentage of standing pigs was calculated as the proportion of pigs in the pen. The overall activity was calculated as the percentage of standing and sitting pigs in the pen.

Behavioural and tail posture differences between T- and C-pens were analysed using the Generalised Linear Mixed Model procedure (GLIMMIX) with group (T-pens vs. C-pens), time of day (morning vs afternoon), day before outbreak (day -1, -2 and -3), days post wean (day 9-17, day 18-26, day 27-35, day 36-45) as fixed effects and pairs of pen (T-pen with C-pen) as a random effect. Interaction was present between group and day with regards to the outcome *percentage of tails down. A*ll other interactions between group and fixed effects were non-significant in the analyses and these were removed from the models.

2.7.2 Tail damaged pigs and tail posture (video)

Effect of the number of tail damaged pigs on day 0 (pen level categorization: 4-5 injured tails, 6-8 injured tails or >8 injured tails) on the percentage of tails down based on video observation on day -1, -2 and -3 were analysed using GLIMMIX with injured tails on day 0, day before outbreak and time of day as fixed effects and pen as random effect. Results are presented as mean, ± SE.

2.7.3 Live observations (tail posture)

Tail scoring and live observations of tail posture were performed three times weekly (on Monday, Wednesday and Friday). Therefore, depending on the day of the week of the tail biting outbreak, the previous tail posture recording was carried out either two or three days earlier. Therefore, in the statistical model, tail posture on day -2 and -3 were grouped in one category named day -2/-3. The same categorizing principle was used for day -4/-5 and day -6/-7. Live observations of tail posture were analysed by GLIMMIX with repeated measurements on pen level and number of active pigs and day as fixed effects.

2.7.4 Victim characteristic, weight categorization and litter origin

Pigs which were scored with a tail wound or scratch at least once after weaning were characterized as a victim (binary variable). Pigs within pen were categorized into four weight groups (25 percentiles) according to weaning weight. The risk of becoming a tail biting victim was analysed using GLIMMIX with sex, victim at weaning, litter origin and weaning weight category as fixed effects. Pen and batch was included as random effects. Correlation between average weaning weight (mean) at the pen level and the onset of a tail biting outbreak (days post wean) was analysed using the correlation procedure (Proc CORR).

3. Results

Tail biting outbreaks occurred in 70 of the 74 pens. On the day of the tail biting outbreak (day 0), on average 7.6 (SD 4.3; range 4-27 pigs/ pen) pigs in T-pens had tail damage (scratch and wound). The distribution of tail scores at weaning and on day 0 is listed in Table 3. At weaning 5.7% of the pigs still with a full-length tail (no parts of the tail were bitten off) were scored with tail damage (scratch and wound), whereas on day 0 (tail biting outbreak day) 23.8% had a wound or a scratch. On the day of the tail biting outbreak (day 0) most of the damaged tails were still full length (1.8% had lost the outer part of the tail). On average, tail biting outbreaks occurred 26.6 days after weaning (SD 11.0, range: 9-49 days) in T-pens.

Table 3 about here

3.1 Changes in behaviour prior to an outbreak (Video)

The percentage of tails down (sum of: hanging and tucked tails) and the percentage of active pigs recorded in T- and C-pen are presented in Figure 1. More tails were down in T-pen than in C-pens ($P<0.001$). This variable was affected by the interaction between group and day before outbreak with more tails down on day -1 than on day -2 and day -3 in T-pens, and more tails down on day -1 than on day -2 in C-pens ($P<0.05$), but there was no difference between C-pens on day -1 and -3 or between day -2 and -3. There was no difference between groups (T- vs C-pens) and days in percentage of active pigs (Figure 1).

Figure 1 about here

Results from video recordings of pigs at the feeder, pigs nosing floor/enrichment, pigs nosing body of pen mates or pigs engaged in tail directed behaviour are presented in Table 4. Day before outbreak did not significantly influence any of the recorded behaviours, but there tended to be more tail directed behaviour in T-pens (P=0.06).

Table 4 about here

Figure 2 shows the association between tail posture on day -1, -2, -3 and tail damaged pigs on day 0. On day -1 more tails were hanging in pens with more severe tail-biting outbreaks with 6-8 and >8 tail damaged pigs compared to outbreak pens with 4-5 tail damaged pigs on day 0 (P<0.001). No difference in tail posture between these different groups was observed on day -2 and -3. In addition, more tails were hanging on day -1 than on day -2 and -3 in pens with 6-8 and >8 tail damaged pigs (P<0.001). No difference in tail posture was observed between days in pens with 4-5 tail damaged pigs on day 0.

Figure 2 about here

3.2 Morning vs. afternoon

More pigs were active (40.0% vs 34.8%, ± 0.78 (SE), P<0.001), more pigs were at the feeder (18.1% vs 15.1%, ± 0.26, P<0.001) and more pigs performed explorative behaviour (30.6% vs 27.9%, ± 0.65, P<0.001) in the afternoon/evening than in the late morning. Pen-mate (4.2% vs 4.0%, ± 0.13, P=0.70) and tail directed behaviour (0.9% vs 1.0%, ± 0.11, P=0.28) did not differ between morning and afternoon recordings.

3.3 Changes in tail posture in T-pens (live observations)

Similar to the findings for the video observations, live observations of tail posture showed that there were more tails down on the day of the outbreak (day 0) compared to the days before the outbreak -2/-3, -4/-5 and -6/-7 ($P<0.05$; Figure 3) in T-pens.

Figure 3 about here

3.4 Effect of weaning weight

No correlation was observed between the average weaning weight on the pen level and the time of onset (days post wean) of a tail biting outbreak ($R=0.03$, $N=70$, $P=0.8$).

3.5 Victims

From weaning until the day of the tail biting outbreak, 650 different pigs were observed with a tail wound/scratch. No difference between the sexes were found in the risk of becoming a tail biting victim ($F_{1,2094}=2.51$; $P=0.11$). There was a strong tendency that weaning weight had an influence on the risk of becoming a tail biting victim ($F_{3, 2091}= 2.50$; $P=0.06$). The largest pigs (Top 25th percentile) in a pen tended to be scored more often with tail damage than the smallest pigs.

Pigs originated from 222 different litters in the farrowing stable. Pigs with a scratch or tail wound originated from 88 different litters (128 pigs: range 1-4 pigs per litter) and pigs with a tail wound originated from 47 litters (59 pigs, range: 1-3 pigs per litter). The chance of becoming a victim in the weaner period was not affected by litter origin in the farrowing unit ($F_{220, 1941}=0.87$, $P=0.91$). Further, the results showed that pigs with a tail injury at weaning might be at a higher risk of becoming a tail biting victim compared to pigs without a tail injury at weaning ($F_{1, 2096}$=3.4, P=0.07).

4. Discussion

We investigated whether a future tail biting outbreak could be predicted at the pen level based on behavioural changes on day -3, -2 and -1 before an outbreak (day 0). The results showed more hanging tails in future tail biting pens (T-pens) than in non-tail biting pens (C-pens) on the three recording days. The percentage of pigs with their tails down almost doubled in number (based on video recordings) in pens close to a tail biting outbreak compared to control pens. Direct observations of tail posture displayed the same trend, with more hanging tails in tail biting pens on the day of the tail biting outbreak compared to earlier. The large increase in tails down on the pen level could make the measure applicable for use in commercial farms. On average, it was estimated that direct recordings of tail posture took approximately 1-2 minutes per pen. Using tail posture changes, as a measure of a future tail biting outbreak, might give farmers a tool to detect the outbreak in its early stages, stop the damaging behaviour and thereby avoid more severe tail damage.

Results from video recordings in tail biting pens reported 33% tails down on the day before the outbreak (day -1). This was higher than on day -2 and -3. Live observations of tail posture in tail biting pens showed the same increase in tails down from day -3/ -2 to day 0 with an increase from 17% to 30% hanging tails. The resemblance between tails down on day 0 (live observation) and day -1 (video observation) is supported by Larsen *et al.* (2016), who suggests that the change in tail posture from curly to hanging prior to an outbreak occurs, because pigs experience pain in the tail even in the pre-injury stages of tail directed behaviour. The hypothesis that tail posture predicts tail biting is further supported by findings reporting that individual pigs with the tail down and no tail damage had a higher chance of having a tail wound 2-3 days later (Zonderland *et al.*, 2009). The lowered tail might be the pigs attempt to protect the tail and avoid further biting.

Previous studies have shown a correlation between activity and tail biting with higher activity in tail biting pens (Statham *et al.*, 2009, Ursinus *et al.*, 2014). Our results do not support these findings, but the differences between studies could have a number of causes. In the study by Statham *et al.* (2009), the increase in activity prior to an outbreak was only observed in pens with severe outbreaks. A severe outbreak occurred when blood was visible and at least two pigs had severe tail damage (partially tail loss). This may indicate that changes in activity are useful to detect full blown tail biting outbreaks and not as an early warning sign of an imminent outbreak. The finding is further supported by the fact that within tail biting pens no changes in activity level occurred from day -3 to day -1 in the present study. However, other reasons could also explain the differences between our results and previous studies (Statham *et al.*, 2009, Ursinus *et al.*, 2014). First, our study was conducted on weaners, whereas Ursinus *et al.* (2014) and Statham *et al.* (2009) observed changes in activity prior to an outbreak in finishers. Second, we recorded activity as the percentage of standing and sitting pigs, whereas in the other two cited studies active lying or sitting pigs were included in the activity measure. We only included standing/sitting pigs in the activity measure, because we wanted a measure of activity that the stock person could implement in their daily management routine. A third reason for the difference between above mentioned studies, could be due to when the activity was recorded. We recorded activity in the late morning and in the late afternoon/evening, and as in other studies pigs did get more active in the afternoon (Costa *et al.*, 2013, Lahrmann *et al.*, 2014). It is possible that differences in activity between tail biting pens and control pens would have been more pronounced during the daily resting periods. One study reported that tail biting behaviour increased the restlessness of the pigs (Zonderland *et al.*, 2011). This restlessness might be more difficult to detect in periods of the day, where pigs are normally active according to their diurnal activity rhythm.

In accordance with previous studies, no differences in explorative behaviour towards the floor or pen-mates were observed between tail biting pens and control pens (Statham *et al.*, 2009, Ursinus *et al.*, 2014). In addition, the percentage of pigs at the feeder did not differ either, this is in agreement with Wallenbeck and Keeling (2013).

Our results showed an increasing percentage of tails down with an increasing number of tail damaged pigs. This further supports the correlation between tail posture and tail biting. Similarly, Zonderland *et al.* (2009) reported on pig level that pigs with a hanging/tucked tail on the day of the tail biting outbreak had to a larger extent a tail wound compared to pigs with a curly tail.

In control pens on average 15-17% of the tails were down. These numbers indicate that hanging tails are not always damaged. Based on experience gained from the data collection, it may be speculated that tail posture is influenced by the activities of the pigs. By watching the pigs, it was our impression that pigs rooting the floor were more likely to have a tail hanging down compared to pigs walking around. It also seemed as if tails were often down when pigs stopped after running around, and then after a short while, tails curled up again if not damaged. Tail posture according to pig behaviour was not recorded in the present study, and further research is needed to understand how different activities affect tail posture.

Tail damaged pigs were observed in 88 litters (2.6% wounds and 3.1% bite-marks) in the farrowing unit just before weaning. For comparison, 9.2% of the pigs had tail wounds and 36.9% had bite marks at weaning in a Dutch experiment with undocked pigs (Ursinus *et al.*, 2014). A tendency was found, that tail biting victims at weaning had a higher risk of becoming a tail biting victim later in the weaning period. This is in contrast with the study by Ursinus *et al.* (2014), who found no such correlation. Overall these results indicate that it is not likely that future tail biting victims can be predicted based on tail damage in the pre-weaning period.

The largest pigs in a pen (25 percentile) were more often victims than the smallest ones (25 percentile), which is in accordance with some previous findings (Van de Weerd *et al.*, 2005, Zonderland *et al.*, 2011), but in contrast with Munsterhjelm *et al.* (2016), who did not find this difference. Taylor *et al.* (2010) suggested that the heaviest pigs are often the first to eat in the active periods, which might make them more exposed to the tail biting behaviour from other hungry and perhaps restless pigs.

In the present study, we found no difference in sex between victims. As discussed by Lahrmann *et al.* (2017) inconsistencies between studies exist, when the risk of becoming a victim is assessed based on sex.

The present study was conducted under commercial conditions in one herd, but the authors believe that changes in tail posture could be an indicator of a future tail biting outbreak regardless the housing environment. We believe so, as it is probably the victims' reaction to pain in the tail that triggers the change in tail posture from curly to hanging/tucked as discussed by Larsen *et al.* (2016).

5. Conclusion

Percentage of hanging tails was almost doubled in pens close to a tail biting outbreak (day -1), compared to pens seven days or more away from an outbreak. In pens close to an outbreak more tails were hanging on day -1 than on day -2 and day -3. These tail posture changes, based on video observations, were supported by live observation of tail posture showing almost the same increase in percentage of hanging tails from day -3/-2 to day 0. In addition, results showed that in outbreak pens with a higher number of pigs with a tail wound on day 0 there were more hanging tails on day -1. Changes in activity level, explorative behaviour or pen-mate directed behaviour were not evident prior to an outbreak. In conclusion, our results indicate that lowered tails could be a promising and practical measure to detect the damaging tail biting behaviour at the pen level before the behaviour causes severe tail damage.

Conflict of interest

The authors declare no conflicts of interest.

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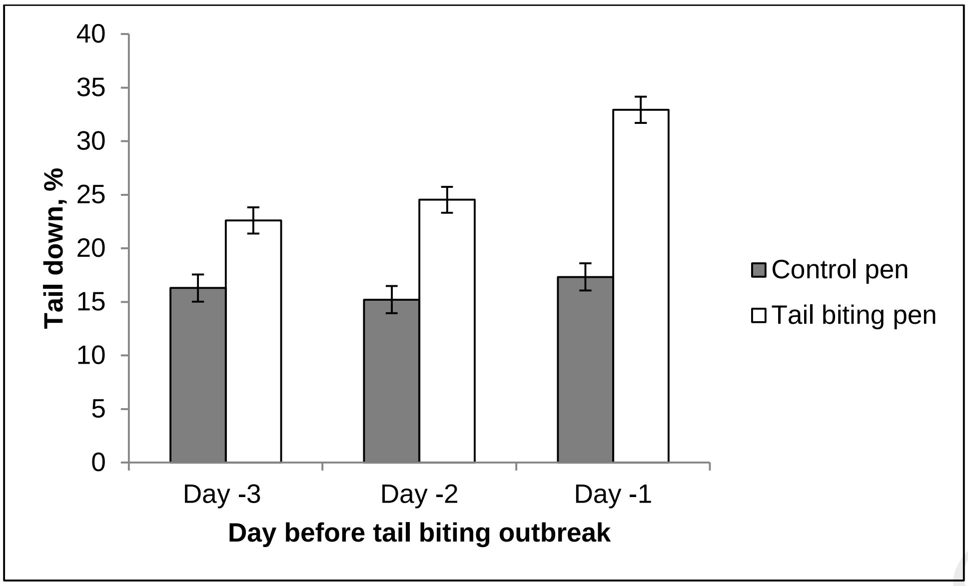
Figure 1. Percentage of hanging tails and percentage of active pigs in T-pens and C-pens on Day -3, Day -2 and Day -1 before a tail biting outbreak (14 half-hourly scan samples 0800-1100h and 1700-2000h on video). Data is presented as LSmeans (± SE).

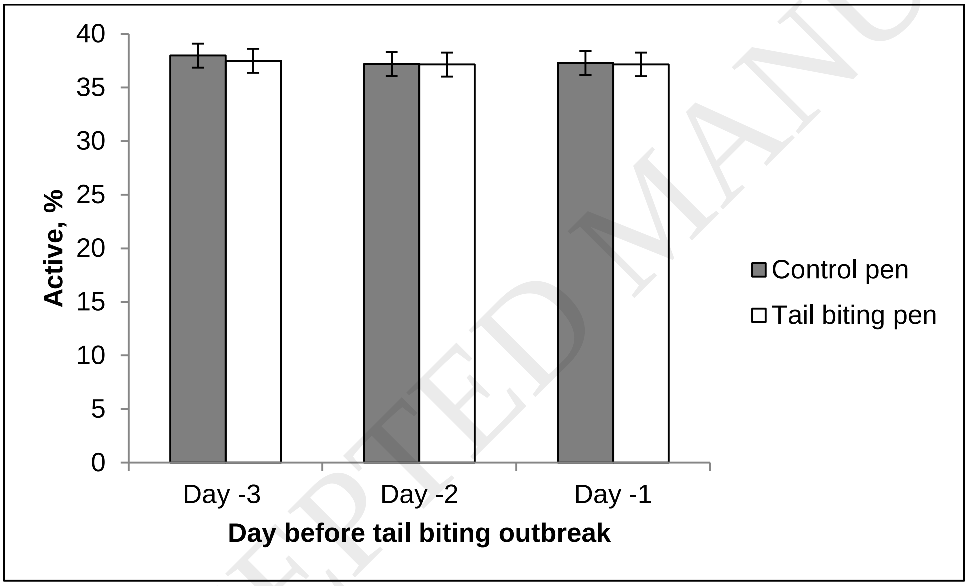
Different superscript *a* and *b* represent significant differences of P<0.05 between day in T-pens. *X* and *y* represent significant differences of P<0.05 between days in C-pens.

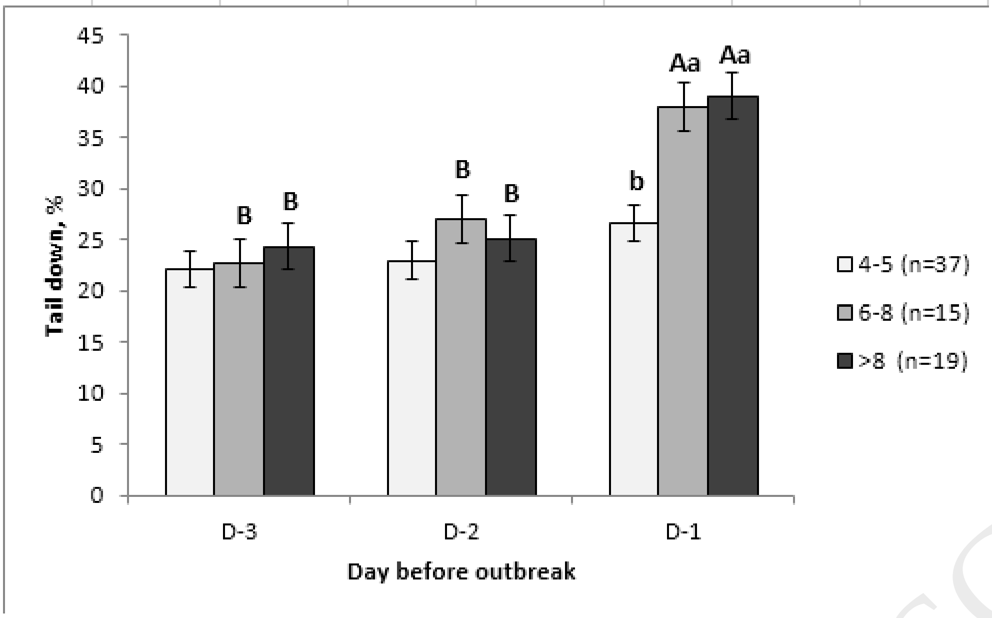
*** = P<0.001 and ns (non-significant) represent differences within day between C-pens and T-pens.

Figure 2. Percentage of tails down on day -3, -2 and -1 according to number of tail damaged pigs on day 0. Pens were classified into three groups; 4-5 (37 pens), 6-8 (15 pens) or >8 (19 pens) tail damaged pigs on day 0. Different small letters a and b indicates significant difference of P<0.001 between pens within day. Different capital letters A and B indicates significant difference between days within group.

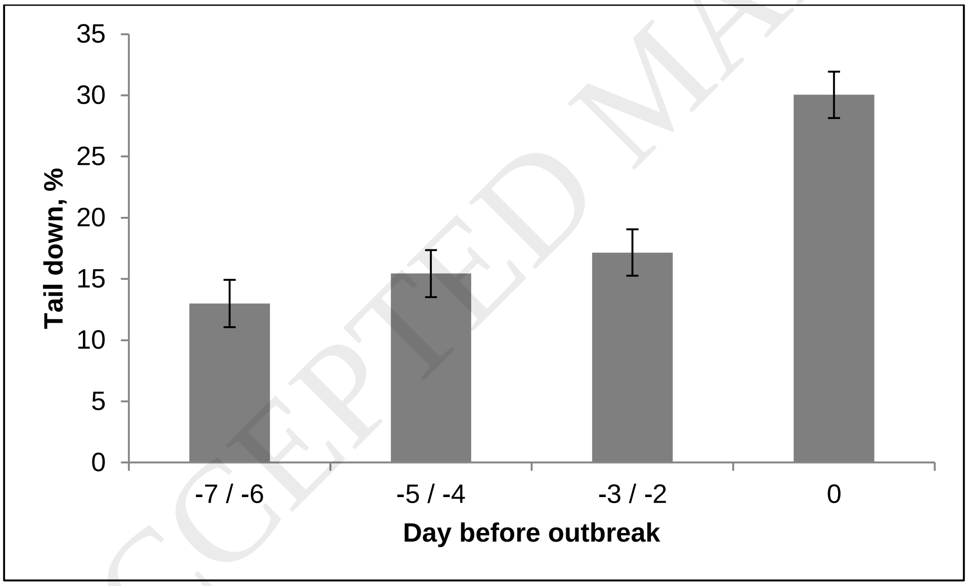
Figure 3. Percentage of tails down assessed by a live observation (pen-side) on day -7/-6, -5/-4 and -3/-2 before a tail biting outbreak and on the day of the tail biting outbreak (day 0). Different superscript (a, b) represent significant difference of P<0.05.


Tail down, %
40
35
30
25
20
15
10
5
0
Day -3
Day -2
Day -1
Day before tail biting outbreak
Control pen
Tail biting pen


Active, %
40
35
30
25
20
15
10
5
0
Day -3
Day -2
Day -1
Day before tail biting outbreak
Control pen
Tail biting pen



45
40
35
30
25
20
15
10
5
0
Tail down, %
Aa
Aa
B
B
b
B
B
D-3
D-2
D-1
Day before outbreak
4-5 (n=37)
6-8 (n=15)
>8 (n=19)



35
30
25
20
15
10
5
0
Tail down, %
-7 / -6
-5 / -4
-3 / -2
0
Day before outbreak

Table 1 Tail injury scoring system

Tail scoring	Description
Damage severity	
No	No visible tail lesion. Earlier lesion is healed
Minor scratches	Minor superficial scratches
Wound	Visible wound and tissue damage
Wound – tail end will fall of	The outer part of the tail has almost been bitten off. During healing tail tip will fall off
Wound freshness	
Intact scab	The wound is covered with a hard dry scab
Not intact scab	The wound is covered with a scab, but cracks in the scab and dried blood/ fresh tissue are visible
Fresh wound – not bleeding (weeping)	Skin is broken, no scab, no blood – only weeping.
Fresh wound - bleeding	Fresh lesion and fresh blood are visible
Tail length	
Intact	Full length tail
Outer part is missing	The outer part of the tail is missing
More than half is missing	More than half of the tail is missing
< 1 cm left of the tail	Less than 1 cm of the tail is left
Swelling	
No	No swelling
Yes	Swollen red tail indicating an infection

Table 2 Ethogram for behaviours recorded on video *(modified after Zonderland et al. 2011)*

Behaviour	Description
Pigs standing or sitting	
Standing/walking	Pigs are standing still or moving around on all four feet.
Sitting	Pigs sitting. Body is supported by hind-quarter and the front legs are straight.
Pigs at feed dispenser	
Nose in trough	Pigs with the nose in the feeding trough.
Head against feeder	Pigs less than one-pig-length away from the trough with the head oriented **towards** the feeder. The head is not in the trough, and pigs are not rooting the floor. It looks like pigs are waiting to get access to the feed.
Head away from feeder	Pigs less than one-pig-length away from the feeder without having the head in the trough. The head is oriented **away** from the feeder.
Nose solid floor feeding	Pigs touching, sniffing, rooting or licking the solid floor within one-pig-length from the feeder.
Pigs at drinking bowl	
Drink or nose the drinking bowl	Pigs with the nose in the drinking bowl or pigs with the head close to the drinking bowl sniffing, touching, rooting or biting the drinking bowl.
Pigs nosing enrichment, floor or pen-mate	
Nose enrichment	Touching, sniffing, rooting or biting the enrichment.
Nose solid floor	Touching, sniffing, rooting or licking the solid floor.
Nose slatted floor	Touching, sniffing, rooting or licking the slatted floor.
Nose tail region/ rear end of the pig	Touching, sniffing, rooting, chewing or biting the tail region or immediate surroundings.
Nose pen-mate, body	Touching, sniffing, rooting, chewing or biting other part of the body beside the tail region.
Tail-in-mouth	Chewing, sucking or biting a pen-mate's tail.
Tail posture on standing pigs	
Curly tail	Tail is curly.
Tucked tail/ hanging tail	Tail hanging or tucked into the body.

Tail other	Other tail posture not included in the above mentioned, for example sticking straight out.
Tail not shown	Tail posture is not visible.

Table 3 Tail damage frequency and distribution (%), broken down by damage to intact tails, and damage when part of the tail is missing at weaning and on the tail biting outbreak day (day 0)

Tail score	At weaning (farrowing stable)		Tail biting outbreak (day 0)	
	No.	%	No.	%
No tail injury	2,131	94.3	1,706	76.2
Intact length and...				
Scratches, intact scab	69	3.1	15	0.7
Scratches, scab not intact			17	0.8
Wound, intact scab	57	2.5	311	13.9
Wound, scab not intact			90	4.0
Fresh wound, not bleeding			21	0.9
Fresh wound, bleeding	2	0.1	38	1.7
Outer part of tail is missing and…				
Wound, intact scab			18	0.8
Wound, scab not intact			7	0.3
Fresh wound, not bleeding			5	0.2
Fresh wound, bleeding			6	0.3
Intact, outer part of tail will fall off			5	0.2
Total*	2,259	100	2,239	100

* Some pigs were moved to hospital pens or died between the tail scoring at weaning and day 0.

Table 4 Percentage of pigs at the feeder and percentage of pigs engaged in explorative behaviour, pen-mate directed behaviour and tail directed behaviour on day -3 (d -3), -2 (d -2) and -1(d -1) prior to a tail biting outbreak in T-pens and C-pens.

	T-pens			C-pens			SE	P- value	
	d -3	d -2	d -1	d -3	d -2	d -1		Group	Day
Pigs at feed dispenser, %	16.5	16.5	16.1	17.1	16.8	17.0	0.4	0.16	0.75
Explorative behaviour, %	29.8	29.3	28.4	29.6	29.1	29.3	0.95	0.86	0.52
Pen-mate directed behaviour, %	4.2	4.0	4.3	3.8	3.9	4.1	0.34	0.53	0.65
Tail directed behaviour, %	0.88	1.2	1.16	0.91	0.73	0.91	0.11	0.06	0.54