

Scotland's Rural College

## Early indicators of tail biting outbreaks in pigs

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## Wedin et al Early Indicators of Tail biting – Highlights

- Tail biting in pigs is unpredictable so early indicators could help farmers
- Behaviour of tail biting vs no tail biting groups observed for 1 week pre-outbreak
- Outbreak groups had fewer curly tails and more tucked tails
- Activity pre-outbreak was no different in outbreak groups
- Day and time of day had little or no effect on these findings

# 1 **Early Indicators of Tail Biting Outbreaks in Pigs**

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3

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8

## 9 **Abstract**

10 Tail biting outbreaks in pig farming cause suffering through pain and stress, and producers lose  
11 revenue due to carcass condemnation. Reliable behavioural indications of when an outbreak is  
12 imminent would provide farmers with tools for mitigating the outbreak in advance. This study  
13 investigated changes in body and tail posture in the 7 days pre-outbreak.

14 Pigs in 15 groups with a mean ( $\pm$  s.d.) group size of 27.5 ( $\pm$  2.6; 427 in total) were raised from  
15 birth under intensive commercial conditions and with tails intact. Twice daily inspections were  
16 made, and a tail biting outbreak was identified (and treated) if 3 or more pigs had fresh tail  
17 injuries, or any pig was seen with a freshly bleeding tail or vigorously biting a tail. Video  
18 footage was recorded continuously to allow pre-outbreak behaviour recording of body posture  
19 (lying laterally, lying ventrally, sitting, standing) and tail posture (curled or uncurled (high, low,  
20 tucked)). Pigs were not individually marked, thus observations were made at pen level by group  
21 scan sampling 12 times per day on day -1, -3, -5 and -7 pre-outbreak. Each outbreak group was  
22 paired with a non-outbreak group of the same age and kept at the facility at the same time which  
23 served as a control. A total of 12 pairs were used. Outbreak pigs had fewer curled tails ( $P =$   
24 0.013) and more uncurled ( $P = 0.008$ ) and tucked tails ( $P < 0.001$ ) than control pigs overall, but  
25 particularly on day -1. Outbreak groups had more tucked tails compared to control on day -7 ( $P$   
26  $= 0.001$ ). Tail posture did not vary over days, or with time of day. Body posture was not

27 different between outbreak and control groups, and although it was affected by time of day,  
28 there was no interaction between outbreak vs. control condition and day, or time of day.  
29 Synchrony of behaviour between pigs (more pigs in the pen showing the same body posture)  
30 was not reduced in outbreak groups. In conclusion, this study supports other recent findings  
31 showing that an increase in tucked tails, and reduced curled tails is an advance indicator of a tail  
32 biting outbreak giving at least 7 days warning, and it does not matter what time of day tails are  
33 observed. Pig farmers could take note of tail posture changes to identify high risk pens.  
34 Considerable variability between pens, and in the timing and magnitude of change means that  
35 technology to automate tail posture detection will be of benefit.

36

### 37 **Keywords**

38 Tail biting, Tail damage, Tail posture, Activity, Indicators, Intact tails

39

### 40 **1. Introduction**

41 Tail biting can be defined as a pig chewing or biting another pig's tail . The problem first came  
42 to the attention of the scientific community in the late 1960's, and was believed to be a result of  
43 intensification, and the earliest studies identified that it had more than one cause (Van Putten  
44 1969; Ewbank 1973). More recent reviews and studies confirm that there are multifactorial risk  
45 factors, although inability of the pig to perform explorative and foraging behaviour is a key  
46 element (Schröder-Petersen & Simonsen, 2001, EFSA, 2007, Taylor et al 2010, D'Eath et al  
47 2014, Valros & Heinonen 2015; Scollo et al., 2017). The recipient of tail biting can suffer from  
48 pain, stress and morbidity (Kritas & Morrison, 2007; Schröder-Petersen & Simonsen, 2001),  
49 which in turn can result in reduced growth rate (Wallgren & Lindahl, 1996), condemnation of  
50 the carcass at slaughter (Kritas & Morrison, 2007; Marques et al., 2012), and if left untreated,  
51 death (Fritchen & Hogg, 1983). Thus, there are direct impacts on both the welfare of the pig and  
52 the revenue of the producer.

53

54 Prevalence of tail biting varies between farms and countries (Taylor et al., 2010), but an  
55 estimated 3 % of tail docked pigs, and around 6-10 % of non-docked pigs, bear lesions from tail  
56 biting at time of slaughter (EFSA, 2007), although these figures are likely to be under-estimates  
57 of the true on-farm prevalence (Lahrman et al., 2017).

58

59 Not all pigs within a pen receive damaging tail biting (Zonderland et al., 2011a), but tail biting  
60 is an indication that welfare is low in the pen as a whole, as it is an expression of poor welfare  
61 (Fritchen & Hogg, 1983). Enrichments, such as provision of rooting material (Beattie et al.,  
62 2001) and/or manipulative objects such as logs (Petersen et al., 1995) or (some) toys (Bracke et  
63 al., 2006) can reduce the tail biting outbreak, as can the removal of the biter and potentially also  
64 the victim pig(s) (Zonderland et al., 2008). However, these methods are costly, and as producers  
65 lack predictability of when an outbreak is approaching (EFSA, 2007), action is usually taken  
66 only once the outbreak is underway. As pigs are omnivores, the presence of blood during an  
67 outbreak encourages further biting from both the primary biter and other pen-mates which can  
68 escalate the problem (Fraser, 1987) and make it more difficult to stop (Schröder-Petersen &  
69 Simonsen, 2001).

70

71 To prevent an outbreak, tail docking, which reduces, but does not fully inhibit the occurrence of  
72 tail biting, is performed to a large extent within the EU (Sutherland et al., 2009; Nannoni et al.,  
73 2014, Valros & Heinonen 2015). This procedure constitutes a mutilation, and should according  
74 to legislation only be used as a last resort, after both space requirement and enrichment has been  
75 addressed (European Commission, 2008). Nonetheless, the vast majority of EU pigs are tail  
76 docked, as producers see no other viable method to mitigate the problem (EFSA, 2007). A  
77 method to alert the producer to an imminent outbreak would allow for preventive treatment and  
78 potentially stop the outbreak from occurring.

79

80 Two recent papers have reviewed the evidence that tail biting could be predicted before an  
81 outbreak using change in behaviour (D'Eath et al., 2014, Larsen et al., 2016). There is evidence  
82 that increased activity (Statham et al., 2009; Zonderland et al., 2011b; But see Lahrmann et al.,  
83 2018a) and lowered tail posture (Statham et al., 2009; Zonderland et al., 2009; Paoli et al., 2016;  
84 Lahrmann et al., 2018a; Larsen, 2018) could be used as predictors of tail biting outbreaks. It has  
85 also been suggested that changes in the timing or nature of activity rather than in the total  
86 amount of activity might be characteristic of tail biting. For example, Statham (2008) found  
87 some evidence for increased activity at night before tail biting outbreaks, while Larsen (2018)  
88 found that activity in the afternoon was higher pre-outbreak in biting groups compared to non-  
89 biting control groups. Zonderland et al (2011b) found that 'restlessness' indicated by the  
90 frequency of posture changes increased before tail biting, and diverse environmental stressors  
91 such as draughts, disturbance and changed feed have been associated with increased tail biting  
92 risk, perhaps because they result in restlessness and irritability (Taylor et al., 2010). Another  
93 potential characteristic of behavioural disturbance and restlessness is a loss of synchrony of  
94 behaviour. In a normal pen, pigs often eat, engage in social and exploratory activities and then  
95 rest more or less as a group.

96

97 To investigate potential behavioural 'early warning signs' of tail biting, the present study  
98 examined five hypotheses in the week preceding a tail biting outbreak by comparing outbreak  
99 and paired contemporary non-outbreak (control) pens: H1) Outbreak pigs show lowered tail  
100 posture H2) Activity increases in outbreak groups H3) Low tail posture and/or activity increase  
101 over time as an outbreak draws closer in outbreak groups H4) Activity and/or tail posture vary  
102 with the time of day differently in outbreak groups H5) Synchrony of behaviour between pigs is  
103 reduced in outbreak groups.

104

## 105 **2. Materials and Methods**

106 This study was part of a larger project working to discover early indications of impending  
107 outbreaks of tail biting in pigs, with the aim to create a technological solution capable of  
108 automatically alerting farmers to risk pens on farm (D'Eath et al., 2018).

109

### 110 *2.1 Ethical Approval*

111 This study was conducted under Home Office licence and has been reviewed and approved by  
112 SRUC's Ethics Committee (ED-AE-27-2016). Steps taken to reduce suffering to pigs are  
113 described in detail in D'Eath et al. (2018), but in brief, housing pigs with intact tails under  
114 commercial stocking density, fully slatted floors and reduced enrichment was done to increase  
115 the risk of tail biting for this study (in order to have some tail biting to study). This was  
116 considered a regulated procedure under the Animals and Scientific Procedures Act 1986 by the  
117 UK Home Office. Pigs were checked and tails inspected at least twice a day. Sick or injured  
118 pigs were immediately given appropriate veterinary treatment in pen or were removed to  
119 hospital pens to aid recovery, or were humanely euthanized. As soon as a tail biting outbreak  
120 was observed (see criteria under behavioural observations below), the biter (if known) was  
121 removed, injured pigs were either treated in pen or removed to hospital pens for treatment if  
122 necessary, and enrichment was added to the pen (shredded paper, additional toys and chews –  
123 wooden blocks, plastic balls).

124

### 125 *2.2 Animals and Husbandry*

126 The study was conducted at SRUC's pig research unit near Edinburgh, Scotland, between  
127 November of 2016 and July of 2017. Pigs of both genders (Large White × Landrace ×  
128 Hampshire) were born and raised at the research facility with tails left intact. Every two weeks,  
129 three groups of approximately 30 pigs each (mean ± s.d. = 27.5 ± 2.6) were weaned, resulting in  
130 15 groups divided into five batches (427 pigs in total). Weaning occurred at 4-5 weeks of age  
131 and the piglets were ear-tagged for ID, sorted by size (small, medium and large) and reared  
132 under intensive commercial conditions in a flat-deck pen with fully slatted floor (2.5 m × 2.5

133 m). Each group was moved without mixing to a grower pen (3.4 m × 3.7 m) and a finisher pen  
134 (3.6 m × 3.8 m) at approximately 9 and 12-13 weeks of age, respectively. Room temperature  
135 was maintained at 30 °C for the first few days after weaning before being gradually reduced to  
136 24 °C prior to the pigs being moved to the grower pens. TinyTags recorded temperature and  
137 humidity (TinyTag Ultra 2, Gemini Data Loggers, UK). Artificial lighting was operated on a 8h  
138 light:16h dark schedule (0700 – 1600h), but the grower rooms had natural ventilation which let  
139 in daylight. Throughout the experiment the pigs were inspected at least twice daily and had *ad*  
140 *libitum* access to water and feed. Feed was provided in a communal trough with a commercial  
141 grower diet (For Farmers HiGro). Basic enrichment in the form of one flavoured porcichew  
142 (East Riding Farm Services Ltd., East Yorkshire, UK) per pen was provided. If a tail biting  
143 outbreak occurred, protocols were immediately followed to safeguard pig welfare and stop the  
144 outbreak (see ethical approval above).

145

### 146 *2.3 Inspecting pigs to identify tail biting outbreaks*

147 Twice daily inspections of all pigs were made by experienced stockworkers or technical staff.  
148 An outbreak, deemed day 0, was declared when at least 3 pigs had a fresh tail wound (defined as  
149 a non-bleeding but weeping or bloodied fresh wound), or at least one pig had a fresh wound  
150 dripping with blood, or if obvious tail biting behaviour which was causing tail damage was  
151 seen. In addition, each pig's tail was scored manually by trained staff three times per week  
152 according to a set protocol incorporating tail damage, wound freshness, tail length and swelling.  
153 The results of this are reported elsewhere (D'Eath et al 2018).

154

### 155 *2.4 Behavioural Observations*

156 Each pen was equipped with two 2D video cameras ("Gamut Professional" Sony Effio Bullet  
157 CCTV Camera (Gamut, Open 24 seven Ltd., Bristol, UK)) mounted in the ceiling; one  
158 capturing the entire pen and one capturing the feeding area as the exposed tails during feeding  
159 made this area a high-risk zone. Cameras were positioned directly above the pen (approximately



160 2.2 m) as an angled camera would increase the risk of pigs obscuring each other's tails and  
161 thereby reduce the amount of recorded tails per scan. The two cameras recorded continuously  
162 24 hours per day and data were stored on a CCTV system (GeoVision software, GeoVisionUK,  
163 Hert, UK).

164

165 When an outbreak was declared, the outbreak group was paired with a corresponding control  
166 group from the same batch that had not had a tail biting outbreak, meaning that the control  
167 group was of the same age and had been in the facility for the same length of time. Day 0 was  
168 set for outbreak and control groups as being the day the outbreak was first identified according  
169 to the criteria above. One control group experienced an outbreak 11 days later, and one outbreak  
170 group had a second outbreak 21 days later, with both outbreaks being used in the present study.

171 Furthermore, one control group was used as a control 35 days after having experienced an  
172 outbreak. Control groups were, when needed, used as control for both of the other groups in  
173 their batch. Therefore, the total number of outbreak – control pairs was 12.

174

175 By using video footage from the week preceding the outbreak, the behaviours for both the  
176 outbreak and control group were recorded for body postures and tail postures according to an  
177 ethogram (Table1). Observation was done by a single observer who was blinded to treatment.  
178 Pigs had ID eartags, but were not marked to make them individually identifiable on video. The  
179 assessed days were day -1, -3, -5 and -7 pre-outbreak. Observation was done through a freeze  
180 frame group scan the first second of every hour during lights on (7:00, 8:00, 9:00, 10:00, 11:00,  
181 12:00, 13:00, 14:00 and 15:00) and once every fourth hour during lights off (3:00, 19:00 and  
182 23:00). All visible pigs and pig tails were recorded. The video footage could be played to ease  
183 recognition if posture was not directly recognisable but only the posture displayed at the freeze  
184 frame time point was recorded. For each pen the observer used the camera that provided the  
185 highest amounts of reliable data, meaning that, depending on the quality of the camera angles,  
186 either one or both cameras in a pen were used for the behavioural scoring.

187

## 188 *2.5 Statistical Analysis*

189 As recording was done on pen level, pen was the statistical unit, with  $n = 1074$  scan samples  
190 completed. Four days from each of Outbreak and Control, 12 pairs of groups, 12 scan samples a  
191 day = 1152. Seventy-eight scans were not completed due to missing video recordings or where  
192 scans were discarded due to staff being in the pen with the pigs. Occasions with less than five  
193 tails visible ( $n = 470$ ) were deleted before analysis of tail posture, to avoid a small number of  
194 visible pigs leading to more extreme proportion rates, resulting in 604 registered recordings of  
195 tail posture. Mean number of pigs visible in a pen was 24.25, with a range of 10 to 31, and mean  
196 number of tails visible was 11.64, with a range of 5 to 27, after recordings with fewer than 5  
197 tails had been removed from the dataset. The 12 recordings per day were divided into the  
198 categories Morning (7:00, 8:00 and 9:00), Late morning (10:00, 11:00 and 12:00), Afternoon  
199 (13:00, 14:00 and 15:00) and Night (3:00 am, 19:00 pm and 23:00 pm).

200

201 Data were plotted and inspected before analysis to identify trends. As part of this, data from the  
202 group which was experiencing a second outbreak, and control groups which had had an earlier  
203 outbreak, or would go on to have an outbreak (see 2.4 Behavioural Observations) were  
204 examined, and found to be typical. Statistical analyses were performed using Genstat 11.

205 GLMM (Generalised Linear Mixed Model) of frequency of body postures were modelled as a  
206 binomial out of the pigs visible at that scan, while frequency of tail postures were modelled as a  
207 binomial of pigs with visible tails. Logit transformations were applied as part of the modelling.  
208 Models included the following random effects: group pair ID, outbreak or control group within  
209 pair and day. Fixed effects included treatment (outbreak or control), days (-7,-5,-3,-1), time of  
210 day (morning, late morning, afternoon, night) and all interactions of these. Inclusion of  
211 treatment in the models allowed H1 and H2 concerning differences in tail posture and activity  
212 between outbreak and control groups to be addressed. The inclusion of day, and day\*outbreak  
213 vs. control treatment interactions in models enabled H3, concerning changes over time (and

214 treatment-dependent changes over time) in tail posture and activity to be addressed. The  
215 inclusion of time of day and time of day\*treatment interactions enabled H4 concerning time of  
216 day effects on tail posture and behaviour to be addressed.

217

218 To investigate H5, than synchrony of behaviour varies between outbreak and control pens, we  
219 calculated 'MaxPosture' the maximum number of pigs at each scan sample which were all  
220 showing the same body posture (sit, stand, lying ventrally or lying laterally), and used this in  
221 GLMM analysis using the models described above (using binomial modelling with the total  
222 visible pigs as the denominator). In a situation of perfect synchrony, all pigs would be showing  
223 the exact same posture as each other in a scan, so the value of MaxPosture, expressed as a  
224 proportion of all visible pigs would be 1, while a value as low as 0.25 would indicate the most  
225 behavioural asynchrony- an equal number of pigs in each of the four different body postures.

226

227 Means for the proportion of body and tail postures reported in graphs and tables were derived  
228 from the raw data (mean  $\pm$  standard error mean;  $M \pm SEM$ ), while F- and p-values were  
229 calculated through modelling. Differences between each treatment and each day, as well as the  
230 interactions of treatment\*day, were examined through the use of LSD tests on predicted means  
231 generated by modelling. Results are reported for  $p < 0.05$ .

232

### 233 **3. Results**

#### 234 *3.1 Tail Posture*

235 There was a significant effect of treatment on tail posture, with outbreak groups displaying  
236 fewer tails curled than control groups ( $F_{1,10,9} = 8.92$ ,  $p = 0.013$ ; Figure 1a). Post hoc tests (LSD)  
237 indicated that outbreak pigs showed a lower occurrence of curled tails than control pigs on day -  
238 1 ( $p < 0.05$ ). There was no effect of day or time of day on the number of curled tails, and no  
239 interactions.

240

241 The proportion of uncurled tails displayed was affected by treatment, with outbreak pigs  
242 showing more uncurled tails than control pigs ( $F_{1, 10.9} = 10.26$ ,  $p = 0.008$ ; Figure 1b). Post hoc  
243 tests (LSD) showed that there was a significant difference between treatments on day -1 ( $p <$   
244  $0.05$ ). There was no effect of day or time of day on the number of uncurled tails, and no  
245 interactions.

246

247 Tail tucking was significantly affected by treatment ( $F_{1, 10.4} = 18.34$ ,  $p = 0.001$ ; Figure 1c) and  
248 day ( $F_{3, 52.5} = 4.98$ ,  $p = 0.004$ ), with outbreak pigs showing a higher proportion of tucking than  
249 control pigs, and more tucked tails were seen on day -1 than on day -7 ( $p < 0.05$ ). Post hoc  
250 testing revealed that outbreak pigs exhibited more tucked tails than control pigs on days -7 and -  
251 1 ( $p < 0.05$ , Figure 1c). There was no effect of time of day on the number of tucked tails, and no  
252 interactions. There was no effect of treatment or day on the proportion of high loose or low  
253 loose tails, although there was a significant time of day effect on high loose tails which were  
254 observed more at night and less in the morning ( $F_{3, 531.3} = 3.73$ ,  $p < 0.011$ ).

255

### 256 *3.2 Body Posture*

257 There were no differences in body posture between control and outbreak groups (Figure 2), and  
258 there were no interactions between control vs. outbreak and any other explanatory variable.

259 Sitting and lying laterally increased over the 4 observed days (Sitting,  $F_{3, 54.8} = 7.38$ ,  $p < 0.001$ ;  
260 Lying laterally,  $F_{3, 69.6} = 3.02$ ,  $p = 0.035$ ), while lying ventrally reduced ( $F_{3, 61.3} = 2.97$ ,  $p =$   
261  $0.039$ ). Time of day also affected all body postures (Lying lateral  $F_{3, 968.4} = 171.63$ ,  $p < 0.001$ ;  
262 lying ventral  $F_{3, 965.8} = 6.79$ ,  $p < 0.001$ ; sitting  $F_{3, 976.6} = 33.34$ ,  $p < 0.001$ , standing  $F_{3, 965} = 103.87$ ,  
263  $p < 0.001$ ). Lateral lying was highest at night and lowest in the afternoon, while sitting and  
264 standing were lowest at night and highest in the morning. There were also significant day\*time  
265 of day interactions for standing and lying ventrally.

266

267 Synchrony of behaviour (MaxPosture) did not differ between outbreak and control groups, and  
268 there were no interactions between outbreak vs. control treatment and day, or time of day. There  
269 was a significant main effect of the time of day, with the lowest values of MaxPosture occurring  
270 at night ( $F_{3,966.8} = 11.13$ ,  $p < 0.001$ ; Back-transformed predicted means, Morning, 0.5796; Late  
271 Morning, 0.6083; Afternoon, 0.5860; Night, 0.5397). This was unexpected, but appears to be  
272 because pigs are either lying laterally or ventrally at night (which count as different postures),  
273 while standing (one posture) is more frequent during the day.  
274

275 **4. Discussion**

276 *4.1 Tail Posture*

277 In support of H1, outbreak groups did show altered tail posture, with fewer curled tails and  
278 more uncurled and tucked tails than control groups. This was significant over the entire study  
279 period, but was most evident on the day before an outbreak. This is in line with a number of  
280 other similar reported findings. Zonderland et al. (2009) and Larsen (2018) found that tail  
281 tucking in an individual pig meant a greater likelihood of tail damage in that pig 2-3 days later.  
282 At the pen level, Lahrmann et al. (2018a) found that outbreak pens had more hanging/tucked  
283 tails than control pens in the last 3 days pre-outbreak, while Statham et al. (2009) found that  
284 pens that would later go on to exhibit a tail biting outbreak (later than 11 weeks of age) showed  
285 more tail tucking at 7 and 11 weeks of age than non-outbreak pens. Finally, in a related study  
286 from this programme of work and in a population consisting of some of the same outbreak  
287 groups as those used here, an automated algorithm was used to measure tail posture from 3D  
288 camera data and found that the proportion of low or tucked tails detected were greater in  
289 outbreak than in control groups, increased over time pre-outbreak and were positively correlated  
290 with tail injury (D'Eath et al., 2018).

291

292 Tucked tails increased closer in time to outbreaks, but surprisingly there was no interaction  
293 between control vs. outbreak and day, suggesting that change over days was not affected by  
294 control vs. outbreak condition. We had expected (H3) a control vs. outbreak\*day interaction to  
295 show that control groups remained the same while changes over time took place in the outbreak  
296 groups as the outbreak grew nearer. The graphs in figures 1-3 visually suggest that the lack of  
297 an effect that we found might be because there are already differences in the tail metrics  
298 between control and outbreak groups on day -7, and that any further divergences are small. For  
299 tucked tail (figure 3) this impression can be supported by the post-hoc statistics which show that  
300 a significant difference in the proportion of tucked tails between outbreak and control groups is  
301 present already on day -7. Video analysis going further back pre-outbreak than day -7 would be

302 needed to identify the point at which tail tucking begins to diverge between control and  
303 outbreak groups, and might reveal the expected interaction over a longer period of time. These  
304 findings are similar to those of Larsen (2018) who found no increase in lowered tails over the  
305 last 3 days pre-outbreak, and suggested that a longer period of study was necessary to find out  
306 when the difference begins. The study of D'Eath et al. (2018) did go further back, and using a  
307 machine-vision algorithm to detect low tails, found a greater proportion of low tails during week  
308 -1 than in week -2 pre-outbreak.

309

310 The present findings also showed that the changes in tail posture were not affected by the time  
311 of day (H4). This either means that the cause of tail posture change (presumably pre-injurious  
312 tail-directed behaviours from pen-mates) remain constantly present, or have a sufficiently long  
313 lasting effect. If lowered tail posture was a brief and transient response to tail-directed  
314 behaviour, then we might have expected to see greater differences in tail posture in outbreak  
315 pigs during the most active periods of the day, and a decline when pigs were relatively inactive.

316

317 In the present study, fewer curled tails (and more uncurled tails) in the outbreak groups than in  
318 the control groups were also seen during the week pre-outbreak. Previous reports have found  
319 that the proportion of curled tails in a pen is reduced during an outbreak (McGlone et al., 1990;  
320 Statham et al., 2009) and that tail tucking is higher during the days leading up to the outbreak  
321 (defined as blood seen from outside of the pen; Statham et al., 2009). It would be feasible that  
322 this behaviour begins pre-outbreak, as victim pigs are exposed to an increased amount of tail  
323 directed behaviours the days leading up to an outbreak, such as tail bites (Statham et al., 2009;  
324 Zonderland et al., 2011a) and non-damaging 'tail in mouth' behaviour (Fraser, 1987; Schröder-  
325 Petersen & Simonsen, 2001). This tail directed manipulation might lead to pigs not curling their  
326 tails if they are trying to protect them from being bitten by other pigs (McGlone et al., 1990).  
327 The findings in the present study therefore indicate that tail posture, in the form of curled,  
328 uncurled and tucked, show potential for being used as predictors of tail biting outbreaks.

329

330 However, tail biting outbreaks are complex, and each outbreak is slightly different from other  
331 outbreaks (Statham et al., 2009; Ursinus et al., 2014). It would therefore be beneficial to repeat a  
332 study like ours under different husbandry conditions and with pigs of different breeds, to see if  
333 the results produced in the present study are applicable to pigs housed under other conditions.  
334 Tail biting is more likely to occur under intensive housing conditions (Beattie et al., 1996) and it  
335 would therefore be interesting to see if the tail postures that here were found to be significant  
336 would be applicable as tail biting indicators in more enriched environments as well.  
337 Furthermore, building on the present study, future research should also look into if the tail  
338 postures used in this study can predict outbreaks even earlier than seven days pre-outbreak.

339

#### 340 *4.2 Body Posture*

341 In the present study, no body posture was significantly different between outbreak and control  
342 groups (H2), and there was also no interaction between outbreak vs. control and day, which  
343 would have picked up different time trends between outbreak and control, such as an increase in  
344 activity over days in outbreak but not control groups (H3). Also we did not find evidence for  
345 differences in body posture between outbreak and control groups dependent on the time of day  
346 (e.g. an increase in active behaviours such as standing during the night; H4).

347

348 Body postures were analysed as simple frequencies here, to avoid the problem of how to  
349 categorise intermediate postures into a single metric. We assume that standing, sitting, ventrally  
350 lying and laterally lying in that order represent a continuum from active to inactive. Some recent  
351 studies have shown the potential of activity as a reliable predictor of tail biting outbreaks.  
352 Statham et al. (2009) found that outbreak groups had a higher proportion of standing and a  
353 lower proportion of sitting and lying inactive as early as four days pre-outbreak, compared to  
354 control groups. However, there were no differences between treatment during observations at  
355 week 7 and 11 (all outbreaks occurred after the observations in week 11; Statham et al., 2009).



356 Zonderland et al. (2011b) studied behaviour in outbreak pens pre-outbreak by studying the  
357 behaviour of the biter, the victim and a control pig (performing and receiving an ‘average’  
358 amount of biting within the pen) in each pen. They found that within the pen, the biter showed a  
359 tendency to sit more than the control, and that victim pigs tended to change posture more often  
360 than controls (Zonderland et al., 2011b). Overall, over the six days leading up to a tail biting  
361 outbreak, there was a decrease in ventral lying and an increase in sitting/kneeling but no effect  
362 was found on standing or lateral lying (Zonderland et al., 2011b). It is interesting that  
363 Zonderland et al. (2011b) found outbreak groups performing sitting more than controls, as  
364 Statham et al. (2009) found a decrease in this behaviour during the days leading up to an  
365 outbreak.

366

367 Ursinus et al. (2014) found that walking and fighting during week 4-7 increased the risk of tail  
368 damage at week 16-23, while inactivity at week 4-7 reduced the risk of tail biting at week 8-15.  
369 They concluded that a higher general activity level (a combination of multiple behaviours) was  
370 associated with increased level of tail damage/ tail biting later on in the pen (Ursinus et al.,  
371 2014). It has been proposed that the increased level of activity could stem from a decreased  
372 amount of resting (Statham et al., 2009) or an increased level of restlessness pre-outbreak, as  
373 indicated by the increased amounts of posture change seen in Zonderland et al. (2011b).

374

375 The above mentioned studies found a positive correlation between activity and tail biting  
376 behaviours or tail biting outbreaks, and it is therefore interesting that there were no such results  
377 in the present study. In the present study, the pen had a fully slatted floor, while in Statham et al.  
378 (2009) the flooring was solid and covered with litter (straw or wood shavings). This could in  
379 part explain the differing results, as provision of straw reduces tail biting behaviour (Beattie et  
380 al., 1996). Furthermore, the present study used 12 pairs of outbreaks and controls, while  
381 Statham et al. (2009) used six, although Statham et al. (2009) had more observations per day as  
382 they recorded the behaviours hourly for four days, compared to the present with 12 times per

383 day for five days. The lower frequency of night-time scans in the present study could also have  
384 contributed to the differing results, as pigs show a diurnal rhythm in behaviour (Andersen et al.,  
385 2008). The behaviours Ursinus et al. (2014) found significant differences for indicated increased  
386 activity, but they were not the same behaviours that the present study looked into, and Ursinus  
387 et al. (2014) compared different time periods to each other while the present study only spanned  
388 over seven days. Regarding Zonderland et al. (2011b), they observed differences between  
389 individuals within an outbreak pen, which makes comparisons to the present study difficult as it  
390 investigated differences between control and outbreak groups. The lack of similarities with  
391 previous studies is therefore not a problem, but rather an addition to the growing scientific  
392 knowledge of how pig behaviour changes prior to a tail biting outbreak.

393

394 Furthermore, not all studies have found changes in body posture pre-outbreak. Zonderland et al.  
395 (2003) did not find any increase in activity in the days leading up to an outbreak, and a recent  
396 study by Lahrmann et al. (2018a) also failed to find any pre-outbreak difference in activity  
397 between tail biting outbreak and control groups.

398

399 The final analysis of body posture involved a metric aimed at capturing the degree of synchrony  
400 between groups, by recording the maximum number of pigs all showing the same body posture  
401 (H5). There was no evidence that synchrony differed between outbreak and control groups, and  
402 there were no interactions between outbreak vs. control and either day or time of day. So we  
403 found no evidence that outbreak groups were less synchronised in their behaviour, or that  
404 synchrony changed over days or with time of day in different ways in outbreak and control  
405 groups.

406

407 *4.3 Implications*

408

409 Our results suggest that an increase in tucked tails and a reduction in curled tails have potential  
410 as early warning signs of tail biting. However, the magnitude of these changes (a difference of  
411 around 15% in the rate of curled vs. uncurled; and a change from around 5% to 15-20% tucked)  
412 may mean that it is difficult for pig caretakers to detect them based on daily visual inspections.

413

414 An automated system to detect changed tail posture in advance of tail biting (as proposed by  
415 Sonoda et al., 2013; Larsen et al., 2016 and D'Eath et al., 2018) still faces a number of practical  
416 challenges. For example, the frequency of tail posture change that indicates that an outbreak is  
417 underway, differs between pens (Statham et al., 2009; D'Eath et al., 2018), which means that  
418 warning would need to be relative to that pen's normal baseline rather than an absolute  
419 threshold. The extent to which factors other than tail biting can also influence tail posture is still  
420 poorly understood (Groffen, 2012). In the future though, it is likely that an increased amount of  
421 welfare and health-related measurements will become automated (Matthews et al., 2016).

422

423 The earlier a potential outbreak pen could be predicted, the easier it would be for the animal  
424 caretaker to stop the outbreak from ever occurring (Fraser, 1987; Schröder-Petersen &  
425 Simonsen, 2001). This could be done through providing enrichment such as straw (Beattie et al.,  
426 1996) or rooting material (Beattie et al., 2001). Lahrman et al. (2018b) have recently shown  
427 that it is possible to successfully mitigate/prevent severe tail biting by introducing enrichment in  
428 response to early warning signs (minor tail injury). Zonderland & Zonderland-Thomassen  
429 (2016) suggested that a system to automatically detect tail biting should be combined with a  
430 mechanism to automatically provide the pigs with enrichment to stop the tail biting.

431

## 432 **5. Conclusion**

433 Outbreak groups showed fewer curled tails and more uncurled and tucked tails compared to  
434 control groups, and within the outbreak groups there were more tucked tails on day -1 than on  
435 day -7 pre-outbreak. This indicates that tail posture has the potential to be used as an early

436 warning indicator of a tail biting outbreak, which could either be directly observed on-farm or  
437 by means of automatic recording (D'Eath et al., 2018). If early warning is used to guide targeted  
438 intervention such as additional enrichment (Lahrman et al., 2018b), this could lead to a  
439 reduction in damaging tail biting outbreaks, thus improving pig welfare and production.

440

441 **Conflicts of interest**

442 None

443

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559



560 **Table headings**

561

562 Table 1 Ethogram of body and tail postures

563

564 **Figure Captions**

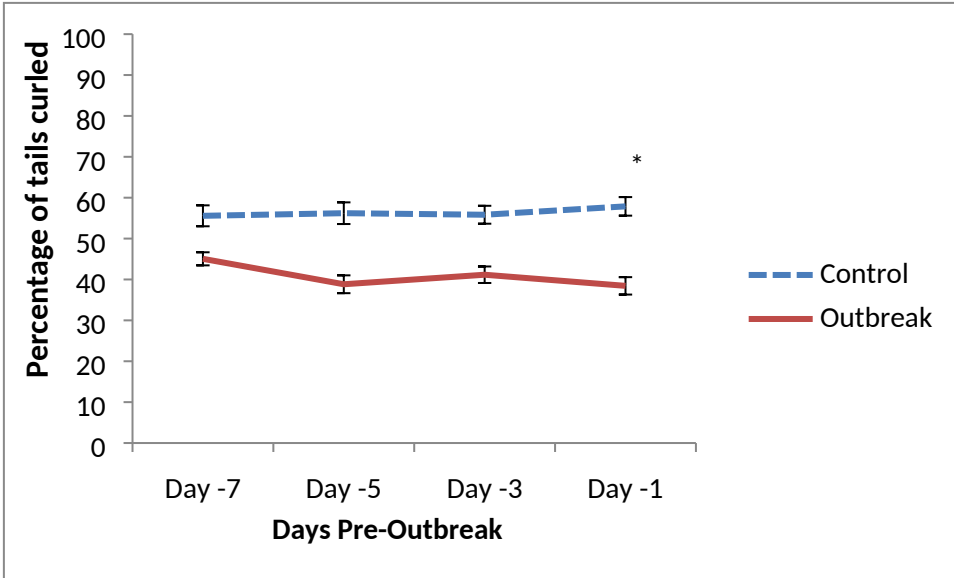
565

566 Figure 1. Mean percentage of curled (a), uncurled (b) and tucked (c) tails observed during the  
567 week leading up to a tail biting outbreak. Means ( $\pm$  SEM) displayed are from raw data. An  
568 asterix indicates significant differences between control and outbreak groups on that day ( $P <$   
569 0.05) derived from Post-hoc LSD tests after GLMM modelling. N = 604.

570

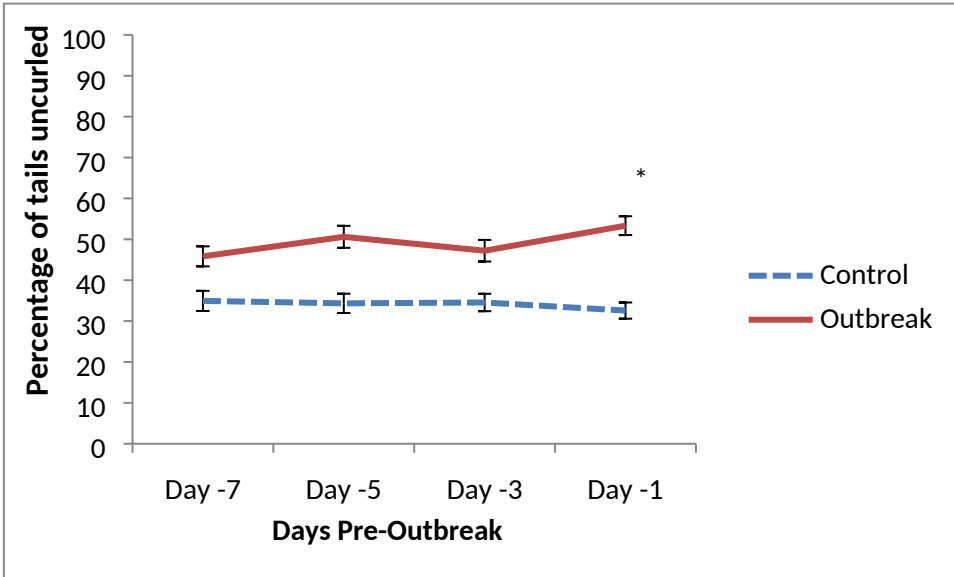
571 Figure 2. Mean percentage of pigs from outbreak (O) or control (C) groups observed standing  
572 (Stand), sitting (Sit), ventral lying (Ven Lie) or lateral lying (Lat Lie) during the week leading  
573 up to a tail biting outbreak. Means ( $\pm$  SEM) displayed are from raw data. There were no  
574 significant differences between the outbreak or control groups.

575



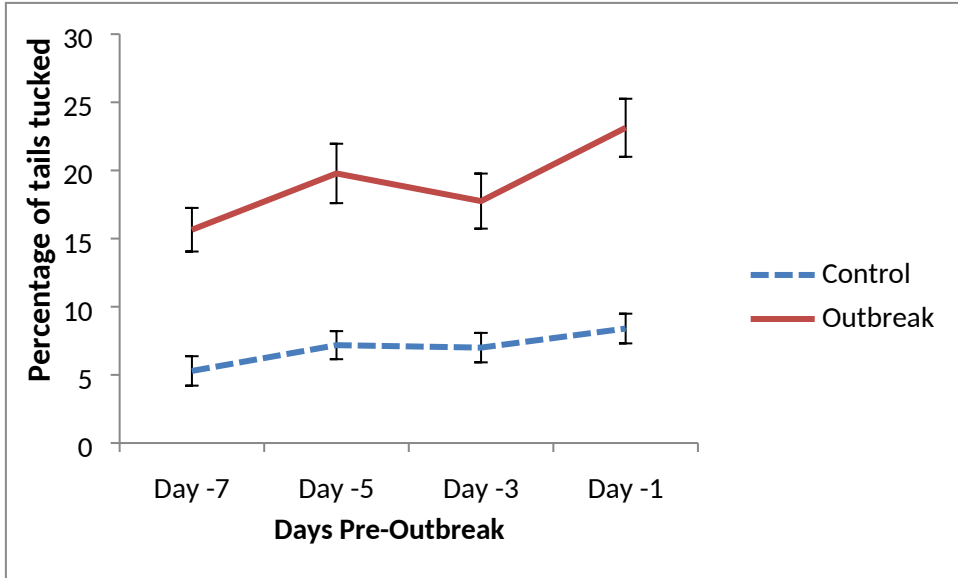
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a)



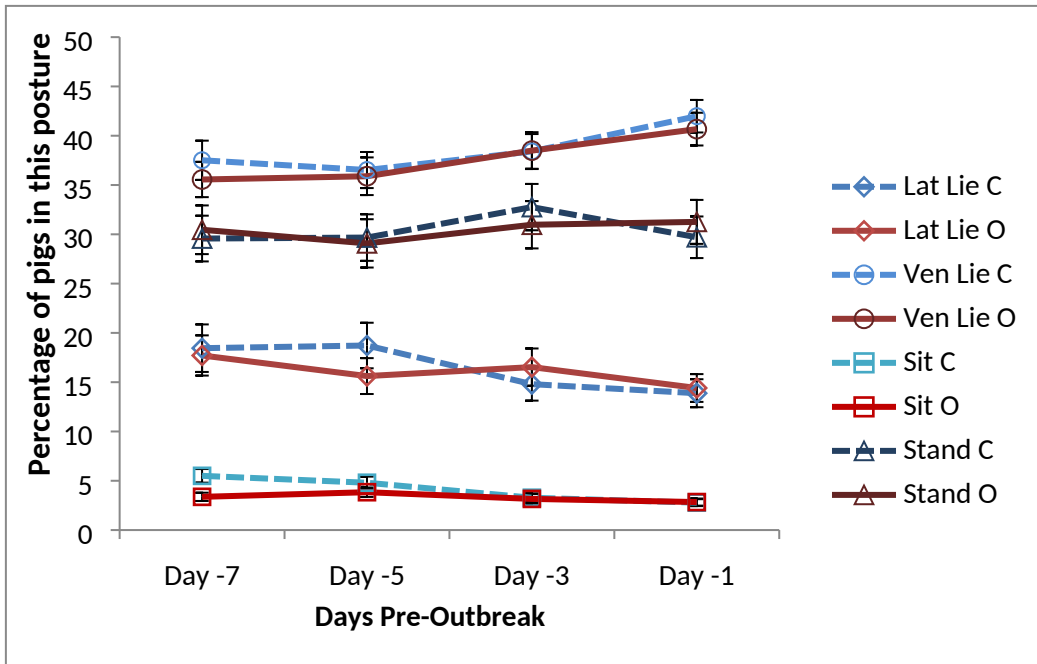
4  
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b)



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8  
9 c)

10 Figure 1. Mean percentage of (a) curled, (b) uncurled and (c) tucked tails observed during the  
 11 week leading up to a tail biting outbreak. Means ( $\pm$  SEM) displayed are from raw data. An  
 12 asterisk indicates significant differences between control and outbreak groups on that day ( $P <$   
 13 0.05) derived from Post-hoc LSD tests after GLMM modelling. N = 604.



1  
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Figure 2. Mean percentage of pigs from outbreak (O) or control (C) groups observed standing (Stand), sitting (Sit), ventral lying (Ven Lie) or lateral lying (Lat Lie) during the week leading up to a tail biting outbreak. Means ( $\pm$  SEM) displayed are from raw data. There were no significant differences between the outbreak or control groups.

1 Table 1 Ethogram of body and tail postures.

2

Type of posture	Posture	Sub-posture	Description
Body	Lying laterally	n/a	The animal is lying on its side, with one shoulder having contact with the floor
Body	Lying ventrally	n/a	The animal is lying on its sternum, with shoulder not touching the floor
Body	Sitting/ kneeling	n/a	The body is supported by two bent back legs while the front legs are straight, or, the body is supported by two bent front legs while the back legs are straight
Body	Standing	n/a	The body is supported by four straight legs
Body	Unknown		Body posture cannot be established
Tail	Curled	n/a	The tail forms a loop
Tail	Uncurled		The tail does not form a loop
Tail		High loose	The tail does not form a loop and is held more than 45 degrees away from the buttocks of the pig
Tail		Low loose	The tail does not form a loop and is held less than 45 degrees away from the buttocks of the pig but is not tucked
Tail		Tucked	The tail does not form a loop and is tucked between the buttocks of the pig
Tail	Unknown	n/a	Tail posture cannot be established

3