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Characteristics of biter and victim piglets apparent before a tail-biting outbreak

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Little is known about the characteristics of biters and victims before the appearance of a tail-biting outbreak in groups of pigs. This study aimed to characterise biters and victims (according to gender and performance) and to quantify their behavioural development during the 6 days preceding the tail-biting outbreak. The hypotheses tested were: (a) biters are more often female, are the lighter pigs in the group, are more restless and perform more aggressive behaviour; and (b) victims are more often male, heavier and less active. Using video recordings we carried out a detailed study of 14 pens with a tail-biting outbreak among the weaned piglets. All piglets were individually marked and we observed the behaviour of biters, victims and control piglets (piglet types). In every pen, each piglet type was observed every other day from 6 days before (D_{-6}) to the day of the first visible tail damage (i.e. day of tail biting outbreak; D_0). While the number of male biters (6 of the 14 biters) and male victims (11 of the 14 victims) was not significantly different ($P = 0.13$), this numerical contrast was considerable. The start weight of victims was significantly ($P = 0.03$) higher (8.6 kg) than those of biters (7.5 kg) and control piglets (8.0 kg). Biters tended ($P = 0.08$) to spend longer sitting/kneeling (3.1 min/h) than controls (1.7 min/h), but no differences were seen in the time spent lying or standing. Victims tended ($P = 0.07$) to change posture more often (restlessness) than controls and chased penmates more ($P = 0.04$) than biters. Victims also performed more ($P = 0.04$) aggressive behaviour than biters and controls. In contrast, biters tended ($P = 0.08$) to be chased by penmates more often and tended ($P = 0.06$) to receive more aggressive behaviour than controls. Furthermore, biters spent longer manipulating the enrichment device ($P = 0.01$) and the posterior/tail ($P = 0.02$) of their penmates than controls and tended ($P = 0.06$) to perform more tail bites than victims. Victims received more posterior/tail manipulation ($P = 0.02$) and tail bites ($P = 0.04$) than controls. It was also noticed that, independent of piglet type, restlessness ($P = 0.03$) increased and the frequency of performed tail bites tended ($P = 0.08$) to increase in the 6 days preceding a tail-biting outbreak. These findings may contribute to the early identification of biters or victims and support the development of strategies to minimise the occurrence of tail biting.

Keywords: pigs, welfare, tail biting, behavioural characteristics

Implications

Tail biting in groups of pigs is a welfare problem and is often not recognised before the first victims with tail damage appear. This study aimed to characterise biters and victims before a tail-biting outbreak occurred. This can provide predictors to identify potential biters or victims at an early stage and take appropriate measures accordingly.

Introduction

Tail biting is an adverse behaviour performed by pigs who are likely to be bored or frustrated, and not only reduces the welfare among pigs but also has significant economic consequences (Bracke *et al.*, 2004). Tail biting is often found among finishing pigs, but is also increasingly found among weaned piglets (Bracke *et al.*, 2004). Thus far, most tail biting studies have focused on the herd or group level, but while the resultant information is useful for evaluating epidemiological risk factors it does not provide a mechanistic understanding of the development of tail-biting behaviour at the individual animal level (Edwards, 2006). Before a tail-biting outbreak occurs, it is often only one or a few pigs that perform this tail-biting behaviour with a higher frequency (so-called biters), and only one or a few victims that receive tail biting with a higher frequency (Zonderland *et al.*, 2010b). However, little is known about the characteristics of such

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biters and victims before and during a tail-biting outbreak. Early recognition of biters and victims in practice would be very helpful in order to apply appropriate measures at an early stage and to prevent a tail-biting outbreak.

Although there is some debate (Blackshaw, 1981; Breuer *et al*., 2005), it has been proposed that biters are the lighter pigs in the pen (Fritschen and Hogg, 1983; Sambraus, 1985). Indeed, Van de Weerd *et al*. (2005) found that the more 'fanatical' biters (individuals who were hyperactive, biting tail after tail during a tail-biting outbreak) were the lighter pigs in the group, whereas victims were the heavier ones. Furthermore, Zonderland *et al*. (2010a) found that female pigs were more often biters compared to intact male pigs. On the other hand, more males (intact and castrated) than females became victims (Penny *et al*., 1972; Valros *et al*., 2004; Kritas and Morrison, 2007). It has also been suggested that biters are more active than their penmates in the week before a tail-biting outbreak (Svendsen *et al*., 2006), show more aggressive behaviour (Hansen and Hagelsø, 1980) and that victims tend to be more inactive (Van Putten, 1980; EFSA, 2007).

This study aimed to clarify the characterisation (gender and performance) of biters and victims and to quantify their behavioural development during the 6 days preceding the tail-biting outbreak. This could improve our understanding of the 'individual piglet contribution' to a tail-biting outbreak and thereby provide predictors to identify potential biters or victims at an early stage.

Material and methods

A library of video records of 96 mixed-sex pens of 10 weaned piglets had been built in a previous experiment (Zonderland *et al*., 2008; see section 'Husbandry'). For present purposes we used the video records for 14 selected pens (see Zonderland *et al*., 2010b), based on the appearance of tail damage and the availability of records for the required observation period. This observation period ranged from 6 days before (D_{-6}) to the first day with a minimum of one piglet with a tail wound or at least two piglets with bite marks (i.e. tail-biting outbreak; D_0).

Husbandry

The 14 identical pens were fitted with partially slatted floors and provided a space allowance of 0.4 m^2 per weaned piglet (Zonderland *et al*., 2008). Each pen contained a dry feeder with two feeding spaces and piglets were fed *ad libitum*. The 140 weaned piglets were not tail docked after birth and not teeth clipped, and the males were not castrated. The average age of the weaned piglets at the start of the experiment was 28.2 (s.d. = 3.2) days and start weight was 7.9 (s.d. = 1.3) kg. At the end of the 32-day weaning period, the average end weight was 26.7 (s.d. = 3.9) kg. The weaned piglets received creep feed for the first 8 days after weaning (14.06 MJ metabolic energy (ME), 180 g/kg protein, 11.88 g/kg lysine and 3.0 g/kg Na (as-fed basis)). Over the next 4 days this was gradually switched to a pre-starter diet (13.81 MJ ME, 175 g/kg protein, 11.54 g/kg lysine and 2.5 g/kg Na), which was fed until day 26. Thereafter, the feed was gradually switched to a starter diet (13.48 MJ ME, 175 g/kg protein, 10.30 g/kg lysine and1.2 g/kg Na), which was fed until the end of the weaning period. A water bowl drinker (situated next to the dry feeder) provided unlimited water. The pens were located in rooms in which the environmental temperature was automatically regulated by forced ventilation. The room temperature was set at 28°C when the piglets entered, 26°C after 5 days, 23°C after 21 days and then 22°C after 28 days until the end of the experiment (32 days). No bedding material was provided, but environmental enrichment devices, either a 0.5-m metal chain suspended from the pen partition or two rubber hose tubes (length: 0.4 m and diameter: 30 mm) tied in a cruciform shape and suspended on a chain (rubber toy). Each pen was digitally video recorded (Poseidon, DVR, eight frames per second) using colour cameras (TC-506CEX) every other day between 1400 h and 1900 h. Spray paint markings (red, blue and green) on the back facilitated individual recognition of the piglets.

Biters, victims and control piglets

On the basis of the previous tail-biting data (Zonderland *et al*., 2010b), the weaned piglet performing the most tail bites in the period from 6 days before (D_{-6}) the first tail-biting outbreak to 6 days after (D_6) was selected as the biter in each of the 14 pens. Similarly, the weaned piglets receiving the most tail bites were designated the victims. In one pen, the biter and victim was the same piglet. To prevent any distortion of the data this piglet was excluded from the observations and the ones with the second highest performed tail bites and the second highest received tail bites were selected instead. Finally, one piglet with an intermediary frequency for both performed and received tail bites was selected as a control in each pen. These were the designated biters, victims and control piglets and observed in depth.

Observations

When the tail biting outbreak became apparent in a pen (i.e. D_0), video recordings of D_{-6}, D_{-4}, D_{-2} and D_0 (observation days) were used for behavioural observations of the biter, victim and control piglet for each of the 14 pens. The 14 tail-biting outbreaks occurred throughout the 32-day observation period (average of 16.6 days after weaning with a standard deviation of 6.7). Due to the labour-intense character of these observations, the piglet types were observed for only a part of the day. From an earlier study on tail-biting behaviour it became clear that the pig's activity was highest in the late afternoon (Zonderland *et al*., 2010b). In addition, other studies showed an activity peak late in the afternoon (e.g. Feddes *et al*., 1993). It was expected that the behavioural differences between the piglet types was highest during the late afternoon and therefore the piglet types were observed between 1600 h to 1610 h, 1630 h to 1640 h, 1700 h to 1710 h, 1730 h to 1740 h, 1800 h to 1810 h and

Table 1 *Ethogram*

Behaviour[1]	Description
Posture	
Lateral lying	Lying on one side with no legs tucked underneath the body
Ventral lying	Lying ventrally with least two legs tucked underneath the body
Sitting/kneeling	Body supported by hind-quarters and stretched front legs or by hind legs and bent front legs
Standing	Body supported by four stretched legs
Performed behavioural states	
Inactive	No activity is shown
Locomotion	Walking without performing any other described behaviour.
Feeding	Head in the food trough
Drinking	Head near the water nipple
Playing	Gambolling, pivoting, rolling, romping[3]
Elimination	Defaecating or urinating
Mounting[2]	Two front legs are placed on the back of a standing or walking penmate
Manipulating (total)	
Floor	Touching, sniffing, rooting, licking the floor
Pen	Touching, sniffing, rooting, licking, biting the pen partition or the feeder
Enrichment	Touching, sniffing, rooting, licking, biting or chewing the enrichment (chain or rubber toy)
Penmate	
Posterior/tail[2]	Touching, sniffing, rooting, licking, biting or chewing a penmate's tail or immediate surrounding
Anterior/ear[2]	Touching, sniffing, rooting, licking, biting or chewing a penmate's ear or immediate surrounding
Ventral/belly[2]	Touching, sniffing, rooting, licking, biting or chewing the ventral part of a penmate's abdomen
Rest body[2]	Touching, sniffing, rooting, licking, biting or chewing other body parts of a penmate
Undefined/unknown	Activities other than the ones described or activities that cannot be properly identified
Received behavioural states	
Mounted[2]	Two front legs of a penmate are placed on the back
Manipulated	
Posterior/tail[2]	A penmate is touching, sniffing, rooting, licking, biting or chewing the tail or immediate surrounding
Anterior/ear[2]	A penmate is touching, sniffing, rooting, licking, biting or chewing the ear or immediate surrounding
Ventral/belly[2]	A penmate is touching, sniffing, rooting, licking, biting or chewing the ventral part of the abdomen
Rest body[2]	A penmate is touching, sniffing, rooting, licking, biting or chewing other body parts
Performed behavioural events	
Tail biting[2]	Biting a penmate's tail, with a sudden reaction of the penmate
Ear biting[2]	Biting of one of a penmate's ears, with a sudden reaction of the penmate
Performed aggressive behaviour	
Pushing[2]	Moving a penmate from its location by non-forceful pushing with the head
Fighting (initiated)[2]	Forceful pushing of a penmate with or without biting (excluding ear biting and tail biting)[4]
Chasing[2]	Chasing a penmate for at least 2 s[4]
Received behavioural events	
Tail bitten[2]	A penmate is biting the subject's tail and elicits a reaction
Ear bitten[2]	A penmate is biting one of the subject's ears and elicits a reaction
Received aggressive behaviour	
Pushed[2]	A penmate moves the subject from its location by non-forceful pushing with its head
Fighting (received)[2]	A penmate pushes the subject forcefully with or without biting (excluding ear biting and tail biting)[4]
Chased[2]	A penmate chases the subject for at least 2 s[4]

[1]Behaviour was recorded as time spent (state) or frequency (events).
[2]This behaviour involved a penmate whose identity was recorded. Normally, the penmate receiving the behaviour was recorded, but in the case of 'Interactions received', the identity of the penmate performing this behaviour was recorded.
[3]Gambolling: running across the pen, occasionally accompanied by jumping/bouncing, nudging, pushing gently or chasing penmates; Pivoting: jumping and turning around the body axis; Rolling: lying on the back and moving from side to side; Romping: combination of mutual pushing and gentle fighting, often accompanied by chasing.
[4]These events may occasionally have a long duration. In that case the event will be scored, whereas the remainder of the time will be scored as undefined/unknown.

1830 h to 1840 h. The piglet types were observed individually using focal sampling (Martin and Bateson, 1986) and appropriate software (Observer XT, Noldus, Wageningen, The Netherlands). In total, 1008 ten-minute video recordings were observed (14 pens × 4 observation days × 6 observation times × 3 piglet types). These recordings were observed in random order by three observers who were unaware of the piglet type. A broad behavioural ethogram was used (Table 1) to characterise the piglet types. This ethogram was partly based on descriptions of pig behaviours from earlier studies (Zonderland *et al*., 2004; Bolhuis *et al*., 2005) and partly on the visibility of the piglets' behaviour.

During observation, two behavioural categories were used: behavioural states (duration of behaviour) and behavioural events (frequency). Piglets' posture and performed behavioural states were recorded of behaviour simultaneously for every 10 min of video observation. Performed behavioural events and received behaviours (states and events) were recorded separately. If the observed piglet performed an unlisted behaviour (state), this was recorded as undefined/unknown. The duration when the behaviour of the observed piglet was not clearly visible was also recorded as undefined/unknown. Furthermore, in some cases the observed piglet spent time interacting with unknown piglets from the neighbouring pen; this time was again recorded as undefined/unknown.

The duration of each posture and behavioural state per piglet type was summed within and over the observation days (D_{-6}, D_{-4}, D_{-2} and D_0) and converted into a behavioural duration expressed as min/h. Similarly, the behavioural frequency was treated and expressed as number per hour. The behavioural duration and frequency per piglet type per observation day were used for statistical analyses. To the observed list of behaviours, three behavioural measures were added.

As a measure of restlessness, the parameter 'Posture changes' (Harris and Gonyou, 1998) was calculated from the number of changes in postures (lateral lying, ventral lying, sitting/kneeling and standing) per 10-min observation period and converted into a frequency of posture changes per hour. The parameter 'Performed aggressive behaviour' was added by summing the frequency of performed fighting, pushing and chasing. Similarly, the parameter 'Received aggressive behaviour' was added by summing the frequency of received fighting, pushed and chased.

The gender, start and end weight (i.e. when moved respectively in and out of the weaning facility) and daily weight gain per individual piglet were available from the previous records (Zonderland *et al.*, 2008).

Statistical procedures

GenStat was used for all statistical procedures (GenStat 11.1; VSN International Ltd, Hemel Hempstead, UK). All fixed factors in the statistical models were tested using the corresponding Wald tests. Differences between pair-wise treatment means were tested using Fisher's least significant difference test.

Differences in performance characteristics (start weight, end weight and daily weight gain) between the three piglet types were tested using a restricted maximum likelihood (REML) procedure with pen as a random factor and piglet type as a fixed factor. Differences in the male : female ratio in each piglet type group were analysed using a χ^2 test on the percentage of male piglets per piglet type group.

To quantify the behavioural development of the three piglet types during the 6 days preceding a tail-biting outbreak, differences in behavioural duration and behavioural frequency were analysed using several statistical procedures. The behaviours – lateral lying, ventral lying, sitting/kneeling, standing, posture changes, inactive, locomotion, feeding, undefined/unknown, manipulation (total), manipulating floor, manipulating pen and manipulating rest of body – were normally distributed. Drinking, playing, manipulating penmate, manipulating enrichment, manipulating posterior/tail, manipulating anterior/ear, manipulating rest of body, mounted, manipulated posterior/tail, manipulated anterior/ear, performed aggressive behaviour and received aggressive behaviour were log-transformed to achieve normal distribution. The above behaviours were all analysed using an ANOVA with blocks of observation day per piglet type per pen, to test the effects of piglet type, observation day and their interaction. Elimination, mounting, manipulating ventral/belly and manipulated ventral/belly were still skewed after log-transformation and were therefore analysed using an iterative reweighted REML (IRREML) procedure with binomial distribution, with piglet type within pens as a random factor and piglet type and observation day as fixed factors. The behavioural frequency (except for performed and received aggressive behaviour) were tested using a similar IRREML procedure, but with a poisson rather than a binomial distribution.

Furthermore, to test whether the behavioural differences between piglet types preceding a tail-biting outbreak were caused by a difference in activity level, all the behavioural durations per piglet type per observation day were expressed as the proportion of being active (ranging from 49% to 100%). The activity-corrected behavioural durations were analysed similar to those described above.

Results

The following tables and figures present the effects of piglet type (including standard error of differences (s.e.d.)) and observation days. Only one significant interaction was found between piglet type and observation period (received tail bites); this is described but the non-significant interactions were omitted.

Gender and performance

There were no significant gender effects on performance characteristics (start and end weight, daily weight gain) and behaviours; therefore, gender was omitted from the end model for both performance and behaviour.

The numerical difference between male victims ($n = 11$) and male biters ($n = 6$) failed to reach significance across the piglet types (χ^2 test, $P = 0.13$; Table 2). Victims had a higher start weight than biters and control piglets. There was no piglet type effect on end weight and daily weight gain.

Posture and posture changes

Control piglets tended ($P = 0.08$) to spend less time sitting/kneeling (1.7 min/h; s.e.d. = 0.6) than biters (3.1 min/h). There were no significant differences between types in the other postures. The overall time spent lying ventrally decreased ($P = 0.05$) over time (24.8, 25.5, 21.6 and 22.2 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 1.6), whereas sitting/kneeling increased ($P = 0.001$) during the observation period (1.9, 1.9, 3.1 and 3.4 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.4).

Control piglets tended ($P = 0.07$) to change posture less often (38.9 times/h; s.e.d. = 3.7) than victims (41.4 times/h). At D_{-4} and D_{-2}, victims showed more posture changes than control piglets (Figure 1). The frequency of posture changes increased ($P = 0.03$) during the observation period (34.9, 34.5, 39.4 and 41.8 times/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 2.8).

Table 2 *Male : female ratio and the predicted mean and s.e.d. of start weight, end weight and daily weight gain per piglet type (including* P*-values)*

	Biter	Victim	Control	s.e.d.	*P*-value
Male : female ratio	6:8	11:3	7:7		ns*
Start weight (kg)	7.5[a]	8.6[b]	8.0[a]	0.37	0.03
End weight (kg)	26.6	29.1	28.1	1.26	ns
Daily weight gain (g/day)	530	570	557	32.7	ns

[a,b]Means within a row with different superscripts are significantly different at $P < 0.05$.
*χ^2 test ($P < 0.05$) on the percentage of male piglets per piglet type.

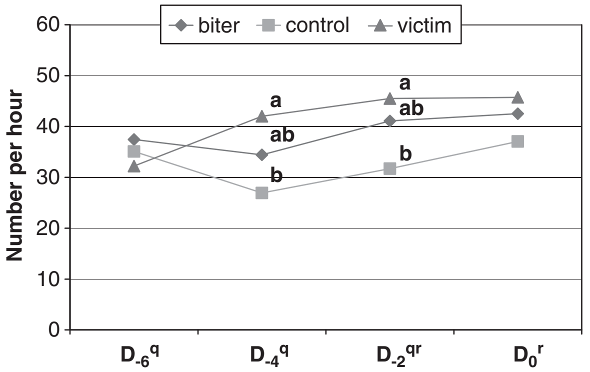

Figure 1 The predicted mean frequencies (times/h) of posture changes per piglet type (biter, victim and control piglet; s.e.d. = 3.7) on each observation day (s.e.d. = 2.8). Different superscripts between piglet type (a, b) and between observation days (q, r) indicate a significant difference ($P < 0.05$). No interaction between piglet type and observation period was found.

Aggressive behaviour

Victims were chasing ($P = 0.04$) their penmates more often (0.23 times/h; s.e.d. = 0.1) than biters (0.04 times/h). Furthermore, victims showed ($P = 0.02$) aggressive behaviour more often (4.09 times/h; s.e.d. = 0.7) than both biters (2.06 times/h) and control piglets (2.40 times/h; Figure 2). In contrast, biters tended ($P = 0.08$) to be chased by penmates more often (0.32 times/h; s.e.d. = 0.1) and tended ($P = 0.06$) to receive more aggressive behaviour (4.25 times/h; s.e.d. = 0.7) than controls (0.11 and 2.43 times/h, respectively). The frequency at which piglets were pushed by a penmate increased ($P = 0.02$) over time (1.1, 1.0, 1.1 and 2.1 times/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.4.

Despite a tendency ($P = 0.06$) for biters to receive more aggressive behaviour than controls there was no significant difference between piglet type across the observation days (Figure 2).

General behaviours

The general behaviours consisted of inactivity, total manipulation, locomotion, playing, feeding, drinking, mounting, elimination and undefined/unknown. There were no significant differences in general behaviours between piglet types.

Period effects were found for inactivity and undefined/unknown behaviours. Piglets' inactivity decreased ($P = 0.01$) during the observation period (26.6, 26.4, 23.1 and 21.0 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 1.8), whereas the average time spent in undefined/unknown behaviours increased (11.7, 14.5, 15.3 and 17.8 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 1.2).

Manipulation behaviour

Biters tended ($P = 0.09$) to perform more total (directed at either floor, pen, penmate or enrichment) manipulative behaviour (13.9 min/h; s.e.d. = 1.6) than control piglets (10.3 min/h; Table 3). Of total manipulation, biters spent longer manipulating the enrichment device (1.8 min/h; s.e.d. = 0.4) compared to control piglets (0.5 min/h), but there were no other detectable piglet type effects.

Total manipulation behaviour decreased ($P = 0.04$) during the observation period (13.6, 11.0, 12.0 and 10.9 min/h at

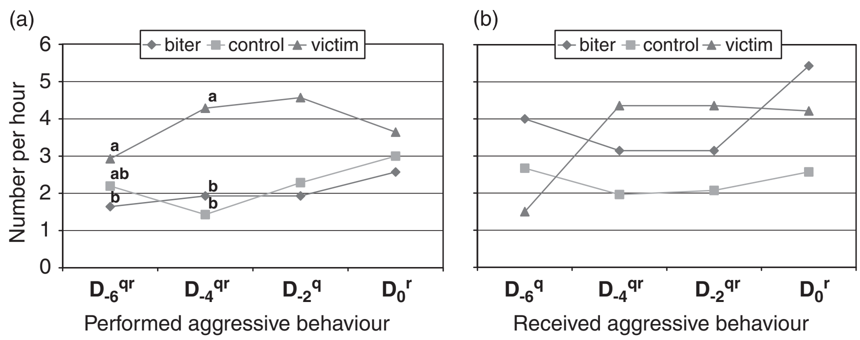

Figure 2 The predicted mean frequencies (times/h) of performed aggressive behaviours (a) per piglet type (biter, victim and control piglet; s.e.d. = 0.7) per observation day (s.e.d. = 0.7) and received aggressive behaviours (b) per piglet type (s.e.d. = 0.8) per observation day (s.e.d. = 0.8). Different superscripts between piglet type (a, b) and between observation days (q, r) indicate a significant difference ($P < 0.05$). No interaction between piglet type and observation period was found.

Table 3 *Predicted mean duration (min/h) and s.e.d. of total manipulation, manipulating the floor, penmate, enrichment device and pen per piglet type (biter, victim and control piglet) and the* P*-values of piglet type and observation period*

					P-value	
	Biter	Victim	Control	s.e.d.	Type	Observation period
Total manipulation	13.8^{z}	11.6^{yz}	10.3^{y}	1.57	0.09	0.04
Floor manipulation	8.6	7.7	6.8	1.19	ns	0.003
Penmate manipulation	2.5	2.2	1.9	0.66	ns	0.02
Enrichment manipulation	1.8^{b}	1.0^{ab}	0.5^{a}	0.38	0.01	ns
Pen manipulation	0.9	0.8	1.0	0.19	ns	ns

^{a,b}Means within a row with different superscripts are significantly different at $P < 0.05$.
^{y,z}Means within a row with different superscripts indicate a tendency ($P < 0.10$).

Table 4 *Predicted mean duration (min/h) and s.e.d. for manipulating (received and performed) specific period body parts per piglet type (biter, victim and control piglet) and the* P*-values of piglet type and observation day*

					P-value	
	Biter	Victim	Control	s.e.d.	Type	Observation period
Performed manipulation						
Posterior/tail	0.65^{b}	0.22^{a}	0.26^{a}	0.15	0.02	ns
Anterior/ear	0.58	0.38	0.31	0.19	ns	ns
Ventral/belly	0.06	0.06	0.48	0.27	ns	ns
Rest of body	1.23	1.52	0.88	0.40	ns	0.04
Received manipulation						
Posterior/tail	0.35^{a}	0.47^{b}	0.28^{a}	0.07	0.02	ns
Anterior/ear	0.48	0.38	0.59	0.17	ns	0.004
Ventral/belly	0.29	0.38	0.44	0.25	ns	ns
Rest of body	1.01	1.42	1.38	0.29	ns	ns

^{a,b}Means within a row with different superscripts are significantly different at $P < 0.05$.

D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 1.0). In addition, manipulation of the floor (9.3, 6.5, 8.0 and 7.1 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.8) and of penmates (2.6, 2.6, 1.6 and 2.0 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.4) decreased over the observation period.

Of penmate manipulation, biters directed more at the posterior/tail part of the penmate's body compared to victims and control piglets (Table 4). Victims received more posterior manipulation than biters and controls. Manipulation of the rest of body decreased over the observation period (1.6, 1.4, 0.8 and 1.1 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.3). The frequency of received anterior/ear manipulation increased over time (0.3, 0.5, 0.3 and 0.9 min/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.2).

Correction for activity

After the correction for activity was applied, the significant differences in duration of activities across piglet types was still apparent, except for the trend that biters perform more total manipulative behaviour than control piglets. This difference was no longer found after correction.

Tail and ear biting

Biters tended to perform more tail bites (0.52 times/h; s.e.d. = 0.1) than victims (0.14 times/h; Table 5). The frequency of performed tail bites was higher for biters than victims and controls at D_0 ($P < 0.05$), but no differences were found at the other observation days (Figure 3). A significant interaction between piglet type and observation period was found for received tail bites ($P < 0.05$) and the differences between piglet types varied between observation days (see Figure 3). The frequency of received tail bites was higher for victims than controls at D_{-6} and D_0 ($P < 0.05$), but no differences were found at D_{-4} and D_{-2}. The frequency of tail bites received by victims increased over time (0.2, 0.4, 0.1 and 0.5 times/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.1). For performed and received ear bites and received tail bites, a period effect was found (see Table 5). The frequency of performed ear bites increased over time (0.2, 0.2, 0.1 and 0.5 times/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.2). Similarly, the frequency of received ear bites increased over time (0.1, 0.2, 0.2 and 0.5 times/h at D_{-6}, D_{-4}, D_{-2} and D_0, respectively; s.e.d. = 0.2).

Discussion

With the current characterisation (gender and performance) of biters and victims the results showed that a previous suggestion that biters were more likely to be female (Zonderland *et al.*, 2010a) was not supported by the findings

Table 5 *Predicted mean frequencies (times/h) and s.e.d. of performed and received tail and ear bites per piglet (biter, victim and control piglet) type and the* P*-values of piglet type and observation period*

	Biter	Victim	Control	s.e.d.	*P*-value	
					Type	Observation period
Performed tail bites	0.52^{z}	0.14^{y}	0.16^{yz}	0.14	0.06	0.08
Performed ear bites	0.41	0.16	0.11	0.14	ns	0.007
Received tail bites	0.25^{ab}	0.55^{b}	0.09^{a}	0.16	0.04	0.007
Received ear bites	0.32	0.34	0.14	0.12	ns	0.001

^{a,b}Means within a row with different superscripts are significantly different at $P < 0.05$.
^{y,z}Means within a row with different superscripts inicate a tendency ($P < 0.10$).

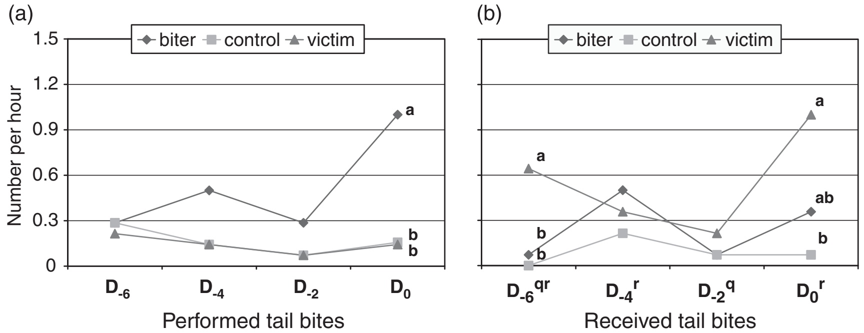

Figure 3 The predicted mean frequencies (times/h) of performed tail bites (a) per piglet type (biter, victim and control piglet; s.e.d. = 0.1) per observation day (s.e.d. = 0.1) and received tail bites (b) per piglet type per observation day (s.e.d. interaction = 0.2). Different superscripts between piglet type (a, b) and between observation days (q, r) indicate a significant difference ($P < 0.05$). For the frequency of received tail bites an interaction between piglet type and observation period was found ($P < 0.05$).

of this study (six male *v.* eight female biters). A numeric difference for more victims to be male than female found in this study was consistent with previous observations (e.g. Penny *et al.*, 1981; Hunter *et al.*, 1999; Zonderland *et al.*, 2010a). We found no effect of gender on activity, although it has been suggested that the lower activity levels of male pigs might make them more attractive targets for tail biting by penmates (EFSA, 2007).

The victims in this study had a higher start weight than biters or control piglets, which is in agreement with Van de Weerd *et al.* (2005). It has been suggested that heavier and more dominant piglets will be the first ones to start feeding during the active periods, and it is conceivable that the exposed tails of feeding pigs could make them a target for tail biters (Taylor *et al.*, 2010; Zonderland *et al.*, 2010b). Indeed, it was found earlier that victims were more often the dominant pigs (Ushijima *et al.*, 2009). In contrast, our hypothesis that biters are the lighter pigs in the group must be rejected because both the start and end weight of biters and controls were similar. Whether so-called 'fanatical' biters (animals that are hyperactive during an outbreak and are moving from tail to tail to bite; Van de Weerd *et al.*, 2005) are the lighter pigs in the group could not be concluded from our data.

With the quantification of the behavioural development of biters and victims during the 6 days preceding the tail-biting outbreak, an indication was found that the restlessness in a pen increased before this outbreak. This was shown by the increase in total activity and posture changes before the outbreak, whereas the time spent lying ventrally decreased. This increase in activity could also reflect an ageing effect of the weaned piglets. However, the probability of an age effect within such a short period is small. Furthermore, a higher general activity in a pen before a tail-biting outbreak was also found by Statham *et al.* (2009) and mentioned earlier by Van Putten (1969) and Svendsen *et al.* (2006).

Neither general activity nor the frequency of posture changes was significantly higher for biters than victims or controls. Conversely, victims tended to change posture more often and were more active than controls, suggesting that victims became more restless before the outbreak. This fact has not been reported before and might reflect greater disturbance of victims being bitten by biters, as these biters increased their tail-directed behaviour.

Biters performed the lowest number of aggressive behaviours but received more than victims and controls. This refutes our hypothesis that biters are more aggressive. A surprising finding was that victims initiated the most aggressive interactions. Certainly, tail bites from the biter can lead to an aggressive reaction from the victim; however, this can only partly explain the received aggression of the biters because this frequency is higher (4.25 times/h) than the frequency of tail bites (0.52 times/h). Another explanation might be that these aggressive interactions reflect confrontations of a dominant piglet (victim) with a subordinate penmate (biter). This is in line with observations by Ushijima *et al.* (2009), who found victims being more often dominant and biters being more often subordinate. Subordinate piglets may become frustrated due to restricted access to food and water during preferred feeding and drinking periods. This frustration may result in the redirection of feeding-related behaviour to penmates or enrichment device, or in a heightened motivation to perform unusual forms of aggressive behaviour directed at the posterior/tail (Hansen and Hagelsø, 1980; Morrison *et al*., 2007).

As expected, biters showed significantly more tail bites as well as longer posterior/tail manipulation. The average duration of posterior/tail manipulation of biters before the tail-biting outbreak remained relatively constant; however, the biters' tail-biting frequency increased by a factor of 3.5 from D_{-2} to D_0. This strong increase in tail-biting behaviour by the biters several days prior to the tail biting outbreak in the pen is in accordance with the exponential increase in tail-biting behaviour from D_{-6} to D_0 reported by Zonderland *et al*. (2010b). This increase in biting behaviour might be explained by the presence of blood (Sambraus, 1985; Fraser, 1987). Indeed, at D_0 some tails with blood were present in the group. However, even though a few bleeding tails were apparent here, they mainly showed bite marks with little fresh blood. Hence, the blood-induced escalation of biting is unlikely to be the sole factor involved. An additional explanation might be that the reaction of the bitten piglet (e.g. vocalising or moving away) has a rewarding effect that increases the biter's motivation to specifically search for more tails to bite (Zonderland *et al*., 2010b).

The overall time spent manipulating the penmates' bodies did not differ between biters, victims or control piglets. This suggests that biters directed their attention primarily to the posterior/tail region, whereas victims and control piglets directed their manipulation more to the other body parts. This might be related to the motivation for sexual behaviour as Schrøder-Petersen *et al*. (2004) speculated that as females approach sexual maturity they show more anogenital investigation, especially of the opposite sex. Indeed, Ford (1990) showed that sexual behaviour between male and female pigs is already different as early as 1 month of age. However, in our study we found no gender effect in the performance of posterior/tail manipulation.

Biters spent longer manipulating the enrichment devices (chain, rubber toy) before the tail-biting outbreak occurred than either victims or controls (both devices drew comparable amounts of attention from the biters). Similarly, pigs with a high propensity to chew suspended ropes subsequently performed more tail-biting behaviour (Breuer *et al*., 2001). Increased manipulation of enrichment devices might be useful in identifying potential biters in practice, for example, using automated recordings of animal material interactions (Zonderland *et al*., 2003). Furthermore, the increase in restlessness might be a good indicator for an upcoming tail-biting outbreak. Therefore, using automated activity monitoring in practice, a relative increase in activity, what may indicate an upcoming outbreak, could be easily detected and the necessary measures taken to prevent an outbreak.

Conclusions

The main aim of this study was to characterise biters and victims according to gender and performance and to quantify the behavioural development during the 6 days preceding a tail-biting outbreak. The main conclusions can be summarised as follows:

- Biters were neither the lighter pigs in the group, nor were they more often female.
- Biters tended to receive more aggressive behaviour than victims or control piglets.
- Though there were no effects of piglet type on general manipulative behaviour, biters directed their manipulation more to the enrichment device and to their penmates' posterior/tail body parts.
- Victims were the heavier pigs in the pen.
- Victims tended to be more restless preceding the tail-biting outbreak. They also performed more aggressive behaviour and received more tail manipulation.

These potential characteristics could conceivably contribute to an early identification of biter or victim piglets and thereby guide the development of practical strategies to minimise tail biting.

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