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Tail-biting behaviour pre-weaning: Association between other pig-directed and general behaviour in piglets

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A R T I C L E I N F O

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A B S T R A C T

Tail biting in pigs is a damaging behaviour and remains an economic and welfare problem in modern pig production. Although tail biting has been extensively investigated, little is known about the behaviour in piglets. The aim of this study was to investigate pig-directed and general behaviour and physical characteristics of suckling piglets in regard to tail-biting behaviour.

Behavioural data from 284 piglets were collected at a commercial Danish pig unit. Prior to weaning, weight parameters were assessed and the frequency of performed/received pig-directed behaviour (tail biting, tail-in-mouth, tail interest, sow-directed biting, ear biting, other biting, displacement and mounting) and performed general behaviour (play-fight, social contact, suckling, locomotion and resting) was recorded for 60 min/piglet. Piglets were classified after the frequency of performed tail biting into high-biters (HB, ≥3 bites, N = 8), low-biters (LB, 1–2 bites, N = 64) and non-biters (NB, 0 bites, N = 212), and further after their tail damage (TD) into victims (V, TD > 0, N = 134) and non-victims (NV, TD = 0, N = 150).

HB were lighter at weaning and had a lower ADG than NB and LB. Both, LB (mean ± s.e.: 0.6 ± 0.2 bouts/h) and HB (0.9 ± 0.3) performed more ear biting than NB (0.2 ± 0.0 bouts/h, P < 0.001), and significant differences between types were found for resting behaviour (percentage of scans 'resting': NB: 19.6 ± 1.5, LB: 12.9 ± 1.9, HB: 14.6 ± 4.2, P = 0.001). HB (0.6 ± 0.2) performed more sow-directed tail biting compared to other biter types (0.1 ± 0.0 bouts/h, P < 0.01), performed significantly more 'other biting' than NB (HB: 0.5 ± 0.2, NB: 0.1 ± 0.0 bouts/h, P < 0.05), and spent a higher percentage of scans in social contact than NB (HB: 14.7 ± 3.4, NB: 8.1 ± 0.7 bouts/h, P = 0.046). LB engaged more in tail interest (1.7 ± 0.2) compared to other types (0.6 ± 0.2 bouts/h, P < 0.001), displaced other piglets more than NB (LB: 1.1 ± 0.2, NB: 0.6 ± 0.1 bouts/h, P < 0.001) and mounted more than NB (LB: 0.4 ± 0.4, NB: 0.2 ± 0.1 bouts/h, P < 0.001). Moreover, LB (6.6 ± 0.9) spent a higher percentage of scans on play/fight behaviour compared to NB (4.6 ± 0.5, P = 0.042). Both, LB (1.0 ± 0.2) and HB (1.6 ± 0.7) were displaced more often than NB (0.6 ± 0.1 bouts/h, P < 0.001). V mounted more than NV (bouts/h V: 0.4 ± 0.1, NV: 0.2 ± 0.2, P = 0.001), and V received tail interest more frequently than NV (bouts/h V: 1.0 ± 0.1, NV: 0.6 ± 0.1, P = 0.041).

This study detected physical and behavioural differences between biter types. The results may suggest that damaging biting behaviours, enhanced activity and social contact are connected. However, no conclusion can be drawn on whether the differences in behaviour are temporal or if they are stable over time. The fact that behavioural differences in regard to tail-biting behaviour were apparent already in piglets may have practical implications for the early prevention and intervention of tail-biting behaviour.

1. Introduction

Tail biting is a damaging behaviour in groups of pigs, characterized by one pig's oral manipulation of another pig's tail, ultimately leading to tail wounds. It does not only lead to reduced welfare of the victim, but is also an indicator of diminished welfare of the biter (Schrøder-Petersen and Simonsen, 2001; Taylor et al., 2010). Tail-biting behaviour is of multifactorial origin and a wide range of risk factors has been described, the majority relating tail biting to inadequate environments, which do not allow pigs to satisfy their basic (behavioural) needs (EFSA, 2007).

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This might result in boredom and frustration, and can in some individuals lead to a redirection of exploration or foraging behaviour towards pen-mates (Fraser et al., 1991; Taylor et al., 2010).

Different types of biter have been proposed (Taylor et al., 2010), and these are suggested to have differing underlying motivations to perform biting behaviour. The 'two-stage biting' is often associated with situations where manipulable destructible materials are lacking (Taylor et al., 2010), connecting biting behaviour with an enhanced motivation to explore. The 'sudden-forceful' biting is associated with an unavailability of resources likely triggering competitive behaviour (Taylor et al., 2010). Causes for 'obsessive/fanatical biting' are largely unknown, however, it is suggested that it is related to a genetic malfunction, causing an enhanced attraction to blood (Taylor et al., 2010).

Tail biting was found to be connected to other manipulative behaviours such as ear and bar biting (Brunberg et al., 2011) and chewing enrichment objects (Ursinus et al., 2014a), suggesting a common motivational background for oral damaging behaviours. Tail biting seems to be associated with behavioural differences between the biters, their victims (Zonderland et al., 2011b), and pigs neither performing nor receiving the behaviour, i.e. 'neutral pigs' (Brunberg et al., 2011; Zonderland et al., 2011b; Ursinus et al., 2014a), although not always consistently so (Ursinus et al., 2014).

A large body of studies investigated tail-biting behaviour in pigs after weaning, as the subsequent tail damage is most prevalent in grower-to-finisher pigs (Scollo et al., 2016; Lahrmann et al., 2017). However, studies often suggest that the precursor of tail biting, the tail-in-mouth (TiM) behaviour, develops at a younger age (Fraser, 1987; Schrøder-Petersen and Simonsen, 2001; Schrøder-Petersen et al., 2003; Taylor et al., 2010). This is in line with studies reporting milder forms of tail damage to be already prevalent in piglets before and at weaning (Ursinus et al., 2014a; Hakansson et al., 2020), indicating that the lactation period is an important phase in the aetiology of biting behaviour. In support of an early development of the behaviour, it has been shown that tail biters are more likely to originate from litters with relatively high levels of tail-biting behaviour (Ursinus et al., 2014).

Given that tail-biting behaviour has been shown to be associated with other damaging behaviour in pigs after weaning, it seems worthwhile to investigate if similar behavioural associations can be detected already in piglets. Furthermore, if behavioural differences between individuals performing or not performing tail-biting behaviour can be detected in piglets, this could be useful in a practical setting as it might enable farmers to take preventive management actions already in the farrowing unit. This study assessed pig-directed and general behaviour as well as physical characteristics in piglets classified after their performed tail-biting behaviour. Focus was especially on exploring the connection between tail biting and other behaviours.

2. Materials and methods

2.1. Study set-up

This study was carried out on a 880-sow farrow-to-grower farm in Denmark under the approval of the farm owner/ manager, and was performed in accordance with the guidelines as stated by the Danish Ministry of Justice ("On the protection and care of pigs under study and animal experimentation", *Order No.17* of January 1 st, 2016, *Act 56* of January 11th, 2017 and *Act 474* of May 15th, 2014). Data collection was achieved without interfering with the general piglet and sow management used on-farm, which followed conventional commercial practice. Piglets within this study were a sub-sample of piglets assessed in a previous study (Hakansson et al., 2020), which were individually ear-tagged at birth and followed until nine weeks of age. At the end of the main study, piglets were moved to an external finisher unit according to normal farm practice.

2.2. Animals and housing

The 284 piglets in this study were born to 25 sows from six farrowing cycles (weekly rhythm), and were housed in free-farrowing pens. The piglets could be identified by individual ear tags. As per farm practice, litter size was reduced to on average 15 piglets (±4) and teeth were ground within 12 h after farrowing. Within 5d *post-partum*, males were surgically castrated and all piglets received an iron injection. Piglets were not tail-docked. No cross-fostering was performed in experimental litters, but if necessary for their survival, piglets were moved to nursing sows. The free-farrowing pens (6 m^2, see Fig. 1) were divided into three parts: a sheltered piglet creep (0.7 m^2) with floor heating (~41 °C until weaning), a slatted dunging area (2.4 m^2) and a concrete resting area (3.6 m^2, floor heating). Sows were daily provided with straw in a rack and a handful of straw was scattered in the pen. Housing units were equipped with windows and the temperature (18–20 °C) was gradually adjusted according to the age of the piglets.

2.3. Weight measurement

The same female observer (FH) made all observations. Individual piglets were weighed (digital scales) within 12 h after birth (w0), at seven days of age (w1) and three days before weaning (avg. weaning age 30d) at four weeks of age (w4). ADG was calculated for the lactation period (birth to on avg. 28d) as the difference in weight between birth and weaning weight divided by the number of days in between. Experimental litters had an avg. birth weight of 1.54 ± 0.2 kg. At weaning, litters contained on average 11.4 (range: 8–14) piglets (avg. 51.2 ± 10.1 % males) with an avg. weight of 8.74 ± 1.2 kg and an avg. daily weight gain of 234 ± 37 g/day. Males and females differed neither in their birth weight (both: 1.54 ± 0.3 kg), their weaning weight (males: 8.76 ± 1.7, females: 8.60 ± 1.8 kg), nor in their daily weight gain (males: 235 ± 54, females: 229 ± 57 g/day). Following the assessment at w4, each piglet received a number on their back using non-toxic paint. Numbers were given consecutively and were independent of the piglet's identification number.

2.4. Behavioural observations

Individual piglet behaviour was recorded and subsequently analysed from video. For each farrowing batch, video recordings took place prior to weaning at w4, and each sow and her piglets was recorded once for 70 min. Sows were either recorded in the early morning (start: 09:00) or the early afternoon (video start 12:00) at randomized order. These times were chosen to minimize disturbance by farm staff. A camera (GoPro Hero 3+, silver edition, hard-box case) was fixed to pen equipment

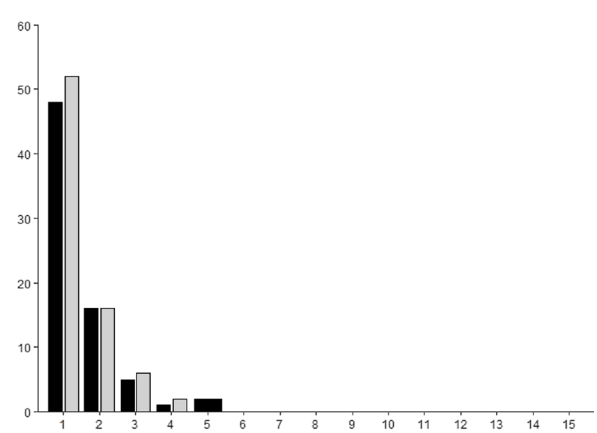

Fig. 1. Number of pigs performing (black bars) or receiving (grey bars) tail bites during 60 min of observation.

approximately 2 m above the floor and recorded the entire pen area. Video recordings were limited to the open area of the pen, as piglets in the creep were not visible. To account for disturbances by mounting the cameras, the first five minutes of each video were labelled as habituation period and were excluded from analyses. Two observers performed video observations, each being responsible of one type of behavioural sampling. The observers were blinded to the piglets' characteristics. Video analyses comprised two types of sampling: behaviour sampling and instantaneous scan sampling.

2.4.1. Behaviour sampling of pig-directed behaviours

To assess pig-directed behaviours, all piglets within each litter were observed for 60 min using behaviour sampling. In the behaviour sampling, focus was especially on the following behaviours: tail biting, tail interest, tail-in-mouth, tail-directed sow, ear biting, belly nosing, other biting, displacement, mounting and udder-massage (see Ethogram Table 1).

For each behaviour, the following was assessed: 1) the number of bouts; 2) the duration; 3) the performer; 4) the receiver (excl. tail-directed sow, udder-massage). Nosing other pigs was not recorded here, but included in the sampling of general behaviours (see below), as it was a common behaviour seen when piglets were active. If an individual stopped performing a behaviour for more than 3 s before starting again, it was counted as a new bout. Data from the continuous sampling were summed into the total number of bouts and total duration in seconds a behaviour was performed per 60 min per piglet.

2.4.2. Instantaneous scan sampling for general behaviour

Scans of each litter were made for 60 min with a 2 min interval giving 30 scans per piglet. At each scan, the identity of the pig and the performed behaviour (see Table 2) were noted for each individual piglet.

Scan sampled data was analysed as the number of scans of each behaviour over 60 min, and was adjusted for visible and inactive scans, where applicable. Hence, scan sampled data is presented as percentage of observed number of scans where piglets are resting (out of all visible scans), i.e., inactivity, and where piglets perform other general behaviours (out of all active scans, i.e. all scans except resting).

2.5. Biter and victim type classification

Due to low frequencies of observed tail biting (i.e. severe biting, causing a reaction in the other pig), bouts of tail-biting and tail-in-mouth (TiM) behaviour were summed and are in following called tail bites. Piglets were classified into three biter-types based on the number of performed bouts of tail bites per hour: low-biter (LB, 1–2 bouts, N = 64), high-biter (HB, ≥ 3 bouts, N = 8) and non-biter (NB, 0 bouts, N = 212). Classification of biter-types was based on the distribution of the frequency of performed bites (Fig. 1).

Furthermore, at w4 all piglets were classified into victims (V) and non-victims (NV), based on previous tail-damage data (Hakansson et al., 2020). Victims were piglets that had any tail lesion (i.e. 'superficial damage', 'bite marks/scratches', 'wound' or 'non-intact length') at w4 (N = 134), while non-victims (N = 150) did not have any lesions.

Table 1
Detailed ethogram of assessed behaviours of piglets pre-weaning used in the continuous behaviour sampling.

Behaviour	Description
Tail biting	Nibbling, sucking or chewing at the tail of a pen mate, causing a reaction from the other pig.
Tail-in-mouth	Gentle nibbling, sucking or chewing of another pig's tail, without causing a reaction in the other pig.
Tail interest	Sniffing, nosing or manipulating the tail of another pig without taking the tail into the mouth.
Ear-biting	Nibbling, sucking or chewing at the ear of a pen mate, potentially causing a reaction from the other pig.
Other biting	Nibbling, sucking or chewing the body of a pen mate (excl. tail and ears), potentially causing a reaction from the other pig.
Tail-directed sow	Sniffing, nosing, nibbling, sucking or chewing at the tail of the sow.
Belly nosing	Repeatedly massaging, nosing, or rooting the belly of a pen mate (same movements as when nursing).
Displacement	Ramming, pushing, head knocking, gambolling, pivoting or nudging a pen mate in an aggressive or playful way causing a submissive reaction (e.g. withdrawal without interaction) from the other pig.
Mounting	Standing on hind legs while having front legs on other pigs back.
Udder massage	Touching, sniffing, rooting, licking, nibbling, sucking or massaging the udder of the sow with the rooting disc (excl. suckling).

Table 2
Detailed ethogram of assessed behaviours of piglets pre-weaning used in the scan sampling.

Behaviour	Description
Play/fight	Play, play-fight or fight (characterized by ramming, pushing, head knocking, gambolling, pivoting, nudging or biting each other in an aggressive or playful way) between two individuals.
Nose-to-nose contact	Touching, sniffing, rooting, licking or nibbling the nose of a pen-mate, without causing a reaction in the other pig.
Nosing/oral manipulation	Touching, sniffing, rooting, chewing, licking, nibbling or sucking part of the body of a pen-mate, without causing a reaction in the other pig.
Sow contact	Touching, sniffing, rooting, licking, nibbling, sucking or biting part of the body of the sow excluding the udder (suckling and teat manipulation).
Suckling/Udder massage	Suckling or touching, sniffing, rooting, licking, nibbling, sucking or massaging the udder of the sow with the rooting disc.
Exploration	Exploring the floor, objects in the pen above floor level or substrate on the floor by sniffing, nosing, rubbing, licking, rooting or chewing it or scraping the floor with a leg.
Locomotion	Standing, walking or running without performing any other behaviour listed here.
Rest	Sitting, kneeling or lying without performing any other behaviour listed here.
Not seen	Piglet cannot be seen.

2.6. Data management and analysis

The variable belly nosing was excluded from further analyses because of a low frequency of occurrence. The variables nose-to-nose, nosing/oral manipulation and sow-contact were combined into the variable 'Social'. For all data analyses the statistical program R version 3.6 was used (R Core Team, 2017). Differences were considered as significant at $P < 0.05$ or as trends for p-values between 0.05 and 0.10. Continuous variables were assessed for normality using Q-Q-plots and histograms. The study unit was the individual piglet. Duration and bouts of pig-directed behaviours were highly and significantly correlated (Spearman rank test, $r = 0.97–1$, $P < 0.001$) and therefore, only bouts were used in subsequent analyses. The distribution of sex among the piglet types (biter or victim) was analysed using Fishers Exact test. Associations between piglet type (biter or victim) and performance parameters (birth-/weaning weight, daily weight gain) were tested using Gaussian linear mixed models (LMER) with type, sex and their interaction as fixed effects and litter as random effect.

The behavioural data were not normally distributed. Pig-directed behaviour were analysed as count data using generalized linear mixed models (GLMER) with Poisson distribution. Data on general behaviour were analysed as fractions using GLMER with binomial distribution. Each behaviour was analysed separately, and each model included biter type, sex and their interaction as fixed effects and litter as random effect. The same approach was used to test the effect of victim type on each behaviour.

Significant interactions between sex and type were found for three variables and are described in the text. Post-hoc pairwise comparisons of the combinations of sex and piglet type were adjusted using Tukey corrections. Non-significant interactions were omitted from the final models.

3. Results

Out of the 284 piglets observed in the study, 72 (25.4 %) were observed to perform between one and five tail bites during the observation period, while 76 (26.8 %) were observed to receive between one and four tail bites. Thirty (10.6 %) piglets both performed and received tail bites. One hundred thirty-four (47.2 %) piglets had a tail lesion ('victims'), and 3.2 % of the piglets had a severe lesion (main sample overall prevalence: 41.7 % & severe tail lesion: 2%, Hakansson et al. (2020)). Biters were distributed over all but one of the 25 litters. A total of 23 (92 %) litters contained at least one LB (range: 1–8), while HB (range: 1–2) were found in 7 (28 %) litters. Six of the seven litters with HB contained both LB and HB. Victims (range: 1–11) were found in all litters. Piglets were on average visible 65 % of the total scans and were active 81.5 % of the visible scans. No differences in visible and active scans were found between victim types. No differences in visible scans were found for the three biter-types, and no differences were found for visible and active scans between sexes. LB were significantly ($P = 0.002$) more often seen active compared to NB.

3.1. Biter types

The distribution of sex between biter-types did not reach significance (Table 3). Biter-type significantly affected ADG and tended to affect weaning weight. HB had a lower daily weight gain compared to NB ($P = 0.048$) and LB ($P = 0.044$), and similarly, tended to be lighter at weaning than NB ($P = 0.062$) and LB ($P = 0.059$).

3.1.1. General behaviour

For the general behaviour, biter-type effects were found for percentage of scans spent on play/fight behaviour, social contact and resting, while an effect of the interaction of biter-type and sex was found for suckling (Table 4).

NB were significantly more often observed resting compared to LB ($P = 0.011$) and HB ($P = 0.012$). When active, LB performed more play-fight behaviour than NB ($P = 0.042$), while HB were more often observed in social contact than NB ($P = 0.046$). Within the NB, females suckled more than males (females: 27.5 ± 1.9 %, males: 26.0 ± 1.7 %, $P = 0.042$). Within the LB, males suckled more than females (females: 23.4 ± 3.0 %, males: 24.7 ± 3.4 %, $P = 0.049$). Between piglet types, female NB suckled more than female LB ($P = 0.03$).

3.1.2. Performed pig-directed behaviour

Besides udder-massage, all performed pig-directed behaviours were affected by biter-type, while displacing and mounting where additionally affected by sex (Table 5).

HB showed a higher frequency of tail-directed behaviour towards the sow than LB ($P = 0.022$) and NB ($P = 0.002$). Similarly, HB performed more ear ($P = 0.002$) and other biting ($P = 0.032$) than NB, with LB in between. Frequency of tail interest was affected by the interaction between type and sex. Female LB performed more tail interest than male LB (female LB: 2.2 ± 0.4, male LB: 1.1 ± 0.2 bouts/h, $P = 0.001$) and had also higher frequencies of tail interest compared to female NB (0.6 ± 0.1 bouts/h, $P < 0.001$) and female HB (0.8 ± 0.5 bouts/h, $P = 0.075$). LB showed the behaviour displacement more frequently than NB ($P < 0.001$), and tended to displace more frequently than HB ($P = 0.078$). Similarly, LB mounted more than NB ($P < 0.001$). Females displaced and mounted other piglets less than males.

3.1.3. Received pig-directed behaviour

For the received pig-directed behaviours, significant type-of-biter effects were found for ear biting and displacement, while an effect of sex was found for other biting (Table 6).

LB were more frequently ear bitten than NB ($P = 0.021$). Both LB ($P = 0.004$) and HB ($P = 0.014$) were displaced more often than NB. Female piglets, independent of type, received more other biting than males.

3.2. Victim types

Numerically, more males were found within V compared to NV (V: 55.2 %, NV: 47.3 %), but this difference was not statistically significant. There was no overall difference in birth or weaning weight between piglets with or without tail lesion (Hakansson et al., 2020), but male V had a greater ADG compared to male NV (male V: 243 ± 56.1, male NV: 226 ± 50.1, $P = 0.009$).

When classified after their tail status into victims and non-victims, only a few behavioural differences were found between the two types: Within the general behaviour, V performed a lower percentage of observed number of scans exploring compared to NV (V: 47.3 ± 1.5 %, NV: 53.7 ± 1.3 %, $P = 0.012$). V performed suckling behaviour in a higher percentage of scans than NV (V: 30.0 ± 1.7 %, NV: 22.1 ± 1.4 %, $P = 0.014$). No other differences were found in the general behaviour of V and NV.

Regarding their pig-directed behaviour, V performed significantly more frequently mounting behaviour compared to NV (bouts/h V: 0.4 ± 0.1, NV: 0.2 ± 0.2, $P = 0.001$). Furthermore, victims received tail interest significant more frequently compared to non-victims (bouts/h V: 1.0 ± 0.1, NV: 0.6 ± 0.1, $P = 0.041$). No other differences in performed or received pig-directed behaviour were found between victim types.

4. Discussion

Within this study, we investigated if tail biting in suckling piglets is associated with other performed/received pig-directed behaviour, general activity or body weight development. Piglets were divided into three biter-types: non-, low- and high biter, and were additionally classified based on their level of tail damage into non-victims and

Table 3
Birth- (w0), weaning weight (w4) and ADG (given as mean ± SD) and percentage of males per biter-type (non-biter (NB), low-biter (LB) and high-biter (HB)) and sex.

	Biter-type			Sex		Effects[1]		
	NB	LB	HB	Males	Females	T	S	T × S
N	212	64	8	145	139			
Weight (kg)								
w0	1.6 ± 0.3	1.5 ± 0.3	1.3 ± 0.3	1.5 ± 0.3	1.5 ± 0.3	ns	ns	ns
w4	8.7 ± 1.7^A	8.8 ± 1.9^A	7.3 ± 1.1^B	8.8 ± 1.7	8.6 ± 1.8	0.052	ns	ns
ADG (g)	232 ± 54.6^a	236 ± 58.6^a	191 ± 38.8^b	237 ± 53.8	230 ± 57.0	0.047	ns	ns
Males (%)	52.8	46.9	37.5			ns[†]		

Mean with different superscript letters in a row indicate differences at $P < 0.05$ (small superscripts) or $P < 0.1$ (capital superscripts).
[1]Significance of piglet type (T), sex (S) and their interaction (T × S) is indicated.
[†]Fishers exact test used for comparison of sex between groups.

Table 4
Percentages of observed number of scans (means ± s.e.) where piglets classified after their biting behaviour (non-biter (NB), low-biter (LB) and high-biter (HB)) were resting (out of number scans visible) and performing other general behaviours (out of number of scans active).

	Type			Sex		Effects[1]		
	NB	LB	HB	Males	Females	T	S	T × S
Resting	19.6 ± 1.5[a]	12.9 ± 1.9[b]	14.6 ± 4.2[b]	18.8 ± 1.7	16.7 ± 1.7	0.001	ns	ns
Active								
Play/fight	4.6 ± 0.5[a]	6.6 ± 0.9[b]	3.6 ± 1.5[ab]	5.5 ± 0.6	4.6 ± 0.5	0.024	ns	ns
Soc. contact	8.1 ± 0.7[a]	10.4 ± 1.0[ab]	14.7 ± 3.4[b]	8.7 ± 0.9	8.8 ± 0.7	0.014	ns	ns
Exploration	51.4 ± 1.2	48.0 ± 2.0	52.4 ± 3.9	50.4 ± 1.5	51.2 ± 1.3	ns	ns	ns
Suckling	26.7 ± 1.4	24.0 ± 2.3	17.2 ± 3.4	25.6 ± 1.6	26.0 ± 1.6	–	–	0.014
Locomotion	9.2 ± 0.7	11.0 ± 1.1	12.1 ± 3.2	9.9 ± 0.8	9.5 ± 0.7	ns	ns	ns

Mean with different superscript letters in a row indicate differences at P < 0.05 (small superscripts) or P < 0.1 (capital superscripts).
[1] Significance of piglet type (T), sex (S) and their interaction (T × S) is indicated.

Table 5
Frequency of performed pig-directed behaviours per hour, given as number (mean ± s.e.) for each biter- type (non-biter (NB), low-biter (LB) and high-biter (HB)) and sex.

	Type			Sex		Effects[1]		
	NB	LB	HB	Males	Females	T	S	T × S
Tail interest	0.7 ± 0.1	1.7 ± 0.2	0.8 ± 0.3	0.7 ± 0.1	0.9 ± 0.1	–	–	0.003
Tail directed- sow	0.1 ± 0.0[a]	0.1 ± 0.0[a]	0.6 ± 0.2[b]	0.2 ± 0.0	0.2 ± 0.0	0.002	ns	ns
Ear biting	0.2 ± 0.0[a]	0.6 ± 0.2[b]	0.9 ± 0.3[b]	0.3 ± 0.1	0.3 ± 0.1	<0.001	ns	ns
Other biting	0.1 ± 0.0[a]	0.2 ± 0.0[ab]	0.5 ± 0.2[b]	0.1 ± 0.0	0.2 ± 0.0	0.037	ns	ns
Displacing	0.6 ± 0.1[a]	1.1 ± 0.2[b]	0.1 ± 0.1[a]	0.8 ± 0.1[a]	0.5 ± 0.1[b]	<0.001	0.012	ns
Mounting	0.2 ± 0.1[a]	0.4 ± 0.4[b]	0.1 ± 0.1[ab]	0.4 ± 0.2[a]	0.2 ± 0.1[b]	<0.001	0.004	ns
Udder-massage	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.3	0.4 ± 0.1	0.4 ± 0.1	ns	ns	ns

Mean with different superscript letters in a row indicate differences at P < 0.05 (small superscripts) or P < 0.1 (capital superscripts).
[1] Significance of piglet type (T), sex (S) and their interaction (T × S) is indicated.

Table 6
Frequency of received pig-directed behaviours per hour, given as number (mean ± s.e.) for each biter- type (non-biter (NB), low-biter (LB) and high-biter (HB)) and sex.

	Type			Sex		Effects[1]		
	NB	LB	HB	Males	Females	T	S	T × S
Tail biting	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	ns	ns	ns
Tail-in-mouth	0.3 ± 0.0	0.5 ± 0.1	0.3 ± 0.2	0.3 ± 0.1	0.4 ± 0.1	ns	ns	ns
Tail interest	0.9 ± 0.1	0.8 ± 0.2	1.0 ± 0.5	0.7 ± 0.1	0.8 ± 0.1	ns	ns	ns
Ear biting	0.3 ± 0.0[a]	0.4 ± 0.1[b]	0.2 ± 0.2[ab]	0.2 ± 0.1	0.2 ± 0.1	0.027	ns	ns
Other biting	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0[a]	0.1 ± 0.0[b]	ns	0.002	ns
Displacing	0.6 ± 0.1[a]	1.0 ± 0.2[b]	1.6 ± 0.7[b]	0.5 ± 0.1	0.6 ± 0.1	<0.001	ns	ns
Mounting	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.3	0.2 ± 0.1	0.2 ± 0.1	ns	ns	ns

Mean with different superscript letters in a row indicate differences at P < 0.05 (small superscripts) or P < 0.1 (capital superscripts).
[1] Significance of piglet type (T), sex (S) and their interaction (T × S) is indicated.

victims.

Within this study, both low-biter (LB) and high-biter (HB) were more often observed in active behaviours and they performed significantly more ear biting than non-biter (NB). Furthermore, HB performed the highest frequency of other biting and sow-directed tail biting. LB on the other hand performed the highest frequency of tail interest, displaced and mounted other piglets more frequently and spent more of their active time in play/fight behaviour. The results agree with previous studies reporting on associations between tail biting and other biting behaviours such as ear and bar biting (Beattie et al., 2005; Brunberg et al., 2011). The differences between piglets performing varying levels of biting behaviour detected in this study agree with Brunberg et al. (2011), who suggested a clear distinctness between biter types. The authors found the individuals performing the highest frequency of bites being generally more specialized in oral abnormal behaviours, while piglets performing a lower frequency adapted a broader range of damaging social behaviours. When comparing general behaviour between the biter types, both the LB and HB were more active than NB, and they additionally engaged more in social contact with their litter-mates, which could indicate a strong connection between damaging pig-directed behaviour and social exploration.

The biters in the current study were displaced more often than NB, which is in line with Zonderland et al. (2011b), who reported that biters were chased more often and received aggressive behaviour more frequently than control pigs. Two possible explanations have often been discussed: the first being that biters are displaced by littermates as a defence to the inflicted biting, and maybe even as a form of retaliation, although this is rarely observed (Taylor et al., 2010). Secondly, it could be speculated that biters might receive more aggressive behaviour because they possess lower hierarchical ranks in a group. Larger or heavier pigs were found to frequently engage and succeed in fights (Meese and Ewbank, 1973; Arey, 1999), and Giroux et al. (2000) found that a higher dominant rank was associated with increased weight gain. This might be supported by the observation by Munsterhjelm et al. (2016) that biters were born significantly smaller than their littermates. Low birth-weight piglets tend to miss nursing bouts (Souza et al., 2014) and are thought to ingest less milk and nutrients than piglets with a higher initial body weight (Fraser and Jones, 1975; Fraser et al., 1979). Although LB and HB did not differ from NB in birth weight, HB had a lower ADG during lactation. It may be suggested that HB were affected by health problems or under-nutrition at some point during lactation, which could have made them more prone to be displaced by their litter-mates due to a change in the social dynamics within a litter (Munsterhjelm et al., 2019). Moreover, it could be speculated if HB adapted biting behaviour to compensate for being less competitive when trying to access the udder, or because they are hungry.

The victims (V) in this study mounted other piglets more often and had a greater weight gain (although this was only true for male V) compared to non-victims (NV), which might support the latter explanation of differences in social ranks between biter and victims. This study did not detect higher frequencies of received tail bites in V, although they received more tail interest than NV. However, when investigating the contribution of individual pigs to a tail-biting outbreak, Zonderland et al. (2011a) found that nearly all individuals within a group received tail bites before tail lesions were prevalent, which may explain that no clear differences between V and NV could be found in regard to received tail bites.

In the development of tail biting, sex is often discussed as risk factor. We found no effect of sex on overall activity, but females received more bites to the body compared to males. Although it is proposed that females perform a higher frequency of tail-biting behaviour (Schrøder--Petersen et al., 2003), and tend to perform more severe bites than males (Brunberg et al., 2011), this was not supported by our findings. However, we found female LB to perform the highest frequency of tail interest. Assuming a successive development of tail-biting behaviour, this enhanced tail interest of female LB could potentially develop into TIM or tail biting, resulting in the enhanced frequency of tail biting in females suggested by the above studies. However, the set-up of the study does not allow for conclusions to be made on whether a behaviour develops into another.

Collectively, this study found behavioural as well as physiological differences in piglets performing and those not performing tail-biting behaviour. These differences could be related to the possible existence of distinct behavioural phenotypes in relation to tail-biting behaviour (Brunberg et al., 2013; Munsterhjelm et al., 2016), or to varying underlying motivational backgrounds in regard to the performed tail biting (Taylor et al., 2010). Taylor et al. (2010) suggested varying underlying motivational backgrounds of tail biting, and proposed three different types of biting behaviour according to those motivations. While some pigs might perform tail biting as a form of normal manipulation when bored, other pigs may be motivated to bite in situations of frustration, for example when being unable to access relevant resources (Taylor et al., 2010). Although it has to be noted that the classification of piglets in biter types in this study was done based on the frequency of performed tail bites, as was also done by Brunberg et al. (2011), it could be speculated whether the biter vary in their motivational background and in their performed tail-biting behaviour. In LB, increased tail interest and social manipulation may suggest piglets in their initial stage in the development of tail biting, while increased damaging biting and social interest in the HB might suggest piglets that already have transformed to damaging biting (Taylor et al., 2010). It has been suggested that pigs displaying the highest levels of tail biting may be motivated to do so by increased metabolic or nutritional needs (Ursinus et al., 2014b), which could hold for the HB piglets that had a history of poor growth.

From the results of this study however, no conclusions can be drawn on underlying motivations of LB, HB and NB. Furthermore, due to the set-up of the study, no conclusions can be made on whether the detected behavioural differences between biter types were stable over time, or if they were merely a reflection of a given situation or a state an individual was in (e.g. sickness, piglet was hungry, tired etc.). No differences in their number of visible scans were found between the biter types during the observation period, but LB spend more of the visible scans active compared to NB. Although assuming that piglet's activity within a litter is largely synchronized (Maletınská and Špinka, 2001; Docking et al., 2008) it has to be presumed that the behavioural expression of some individuals was under-/overestimated.

5. Conclusion

We compared pig-directed and general behaviour in piglets, and found behavioural as well as physical variation in piglets classified after their performed tail-biting behaviour and tail status. Our results indicate that the piglets that do not tail bite are less socially interactive and rest more frequently, whereas piglets that do tail-bite also engage more often in other damaging behaviours and are more active, both generally and socially. Physical and behavioural differences were also found between piglets performing varying frequencies of tail-biting behaviour: piglets performing a lower frequency of tail bites engaged more in play/fight behaviour, while the piglets performing a higher frequency of tail bites where smaller than their litter-mates and performed oral-abnormal, explorative and social behaviours more frequently. Victims received more tail interest and suckled more frequently compared to non-victims. Taken together, tail biters and especially, the individuals performing the most bites seem to be different from their littermates already before weaning. This could aid the detection of early tail-biting behaviour under commercial conditions; however, further research is needed.

Declaration of Competing Interest

The authors report no declarations of interest.

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