

Assessment of welfare in pigs with docked and undocked tails during the weaner stage

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HIGHLIGHTS

- Weaner pigs with undocked tails had more tail and body lesions than docked ones.
- Docked pigs showed a higher incidence of straight tail posture.
- Injuries increased over time due to reduced enrichment use.
- The hormonal profile showed resilience differences based on tail condition and sex.
- Comprehensive welfare assessment is essential for improved management strategies.

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ABSTRACT

Tail integrity is a key welfare target in European pig farming. This study evaluated the welfare condition of weaner (28–84 days old) pigs with docked (D) and undocked (UD) tails on a commercial farm, following National Reference Center for Animal Welfare and WelfareQuality® standards. Animal-Based Measures and the hormonal quantification of cortisol (CORT) and dehydroepiandrosterone sulfate (DHEA(S)) in bristle samples were assessed in 295 pigs distributed in 16 pens. Pigs were born from 24 homogenous sows, distributed across four consecutive weekly batches, and were balanced by sex. Compared with D pigs, UD pigs presented more injuries in the tail ($P = 0.02$) and on the body ($P < 0.01$), with tail biting occurrences peaking halfway through the post-weaning phase. Body injuries increased over time, particularly in UD pigs, correlating with rising stocking density. D pigs displayed a straight tail posture more frequently ($P < 0.01$), suggesting a more positive emotional state. Regardless of tail condition, the use of environmental enrichments declined over time ($P = 0.03$) as novelty diminished. Hormonal analysis revealed sex-related differences in resilience, with females showing higher CORT and CORT/DHEA(S) ratio and lower DHEA(S) levels than castrated males ($P < 0.01$). There was a tendency toward higher CORT/DHEA(S) ratio in UD pigs than D ones ($P = 0.06$), indicating a greater activation of the hypothalamic-pituitary-adrenal axis to restore homeostatic conditions. Multivariate analysis linked body lesions, stress markers, and negative interactions, highlighting welfare's multifactorial nature. Tail integrity alone may be misleading as a welfare indicator. A holistic assessment, integrating physical, emotional, and physiological factors, is crucial for improving management strategies for UD pigs on commercial farms.

1. Introduction

The introduction of the One Welfare concept, which highlights the interconnection between animal, human, and environmental welfare,

marked a pivotal shift in the discussions on livestock farming practices and the role of animal welfare in sustainable food systems (Pinillos et al., 2016). In the past, during the post-war period, societies faced the challenge of increasing food production while reducing the cost of

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animal-based products. The primary goal was to make these foods more accessible to lower-middle-class populations. However, this intensification of farming practices often came at the expense of animal welfare. Over the decades, advancements in animal welfare science with the development of well-known frameworks, such as the Five Freedoms (Brambell, 1965; Webster, 1994), the Five Domains Model (Mellor and Reid, 1994), and the recognition of positive welfare experiences (Mellor and Beausoleil, 2015), have shaped policies and practices. In line with this progress, the European Commission, through its Farm to Fork strategy, is committed to revising farming regulations and improving related livestock welfare standards (EFSA Panel on Animal Health and Welfare, 2022).

Among livestock systems, pig farming has been increasingly scrutinised due to growing public awareness of animal welfare concerns. This greater sensitivity is likely influenced by the fact that pork is the most consumed meat in Europe (EC, 2021). A particularly contentious issue in both public and scientific discussions is tail biting, an abnormal behaviour consisting in pigs biting the tails of their conspecifics, often leading to severe injuries.

Tail biting has a multifactorial aetiology, making its prevention and control a challenging task (EFSA Panel on Animal Health and Welfare, 2007). Among the various contributing factors, genetics play a significant role. The heritability of tail biting appears to be positively correlated with lean growth rate and negatively correlated with back-fat deposition (Breuer et al., 2005). Consequently, selective breeding for high productivity and muscular hypertrophy may inadvertently increase the risk of tail biting. In an effort to mitigate this issue, various strategies have been proposed, including the use of plant extracts for phytotherapeutic purposes (Pastorelli et al., 2022) and environmental enrichment (EFSA Panel on Animal Health and Welfare, 2007). In indoor farming conditions, where manipulable substrates are lacking and the environment is overly simplified, pigs often redirect their natural exploratory behaviour towards other individuals (EFSA Panel on Animal Health and Welfare, 2007; Scollo et al., 2013). Additionally, large group sizes and heterogeneous groups in terms of body weight, age and sex further increase the risk of damaging behaviours, including tail biting (Scollo et al., 2013; Taylor et al., 2010). Moreover, Zonderland et al. (2010) suggested that as females reach sexual maturity (puberty: 150–220 days of age; Patterson et al., 2010), unlike castrated males, they become more active and increasingly interested in exploring the ano-genital area.

If preventive measures are insufficient, tail docking (caudectomy) is commonly practised to reduce the consequences of tail biting, though it does not address the underlying causes of the behaviour (EFSA Panel on Animal Health and Welfare, 2007; Henry et al., 2021; Sonoda et al., 2013). Tail docking is widely recognised as an effective method for controlling tail biting and aggression in pigs, despite being considered an unpleasant procedure (Henry et al., 2021; Nannoni et al., 2014). Undocked pigs are at a higher risk of tail injuries, which can negatively affect their physical (EFSA Panel on Animal Health and Welfare, 2007) and emotional welfare (Camerlink and Ursinus, 2020; Iglesias and Camerlink, 2022). Moreover, the effects of tail biting are twofold: it not only compromises animal welfare (Valros et al., 2020) but also leads to economic losses, due to direct damage to the affected animals and a reduction in their market value (De Briyne et al., 2018; D'Eath et al., 2016).

Over the years, research has led to the development of increasingly effective strategies for evaluating and monitoring animal welfare. Two largely used approaches are the use of Animal-Based Measures (ABMs) and monitoring of hormones related to allostatic load and resilience, such as cortisol (CORT), dehydroepiandrosterone (DHEA), dehydroepiandrosterone sulfate (DHEA(S)) and their ratio (Nannoni et al., 2016; Peric et al., 2023; Scollo et al., 2025). ABMs involve direct measurements and observations of animals during on-site welfare assessments, providing insights into the impact of environmental conditions and management practices (EFSA Panel on Animal Health and Welfare, 2012). These measures include behavioural and health status indicators

(Plut et al., 2023; Welfare Quality®, 2009). ABMs are largely used to assess welfare at different stages of production at farm level, such as cross-fostering in the farrowing unit (Díaz et al., 2018) and transitions between various phases of the breeding cycle (Diana et al., 2019; EFSA Panel on Animal Health and Welfare, 2022). Unlike visual assessments, hormonal indicators measured in bristles provide a retrospective and cumulative evaluation of an individual animal's endocrine status in relation to its environment. Several studies have already shown that assessing CORT and DHEA(S) is a valuable tool for understanding how husbandry conditions affect the welfare of sows and fattening pigs (Bergamin et al., 2019; Montillo et al., 2020; Peric et al., 2023). These hormones serve as markers of allostatic load and resilience, while the CORT/DHEA(S) ratio is considered an index of the catabolic/anabolic balance, due to the synchronized synthesis of these hormones and their opposing effects (Maninger et al., 2009; Montillo et al., 2020; Qiao et al., 2017). Furthermore, DHEA(S) acts as an "anti-stress" steroid, reducing the negative effects of glucocorticoids like CORT (Maninger et al., 2009). Although research has extensively examined body lesions, physiological conditions, and behavioural traits in suckling piglets, relatively few studies have investigated the weaner stage (Fu et al., 2018 and 2019; Tallet et al. 2019; Zhou et al. 2013).

The primary aim of this study was to evaluate the effect of tail docking on the welfare of docked and undocked pigs during the weaner stage (28 to 84 days of age) under commercial breeding conditions, through the assessment of ABMs and the analysis of CORT and DHEA(S) concentrations in bristle samples. Additionally, the study aimed to identify potential correlations between these two assessment methodologies.

2. Materials and methods

The study was conducted according to EU Directive 2010/63/EU. Since the procedures adopted were routine, no formal approval was required.

The animals under test were monitored throughout the entire phase by the evaluation of ABMs, expression of the health and comfort profile, and of activity indicators for behavioural profile and, at the end, by the dosage of two hormones, CORT and DHEA(S), in the bristles.

2.1. Animals and feeding

The study was conducted in a commercial farm, following the usual farming practices, that ensured an acceptable level of welfare, in terms of structural and managerial requirements, according to the standards of the National Reference Center for Animal Welfare (CRENBA, 2018). The piglets were born from 24 sows (parity order between 2 and 6), distributed into four consecutive weekly reproduction rounds, with farrowing occurring within one month. Piglets were progenies of Camborough® sows sired with Goland C21® boars. After balancing, litters consisted of 12.8 piglets on average (ranging from 11 to 14 piglets). The litters in each batch were divided into two groups to create an equal number of pens with docked and undocked weaned pigs. In docked pigs the tails were docked using a hot cautery blade at 2–3 days of age. Male piglets were surgically castrated within 3 days of life (performed with anesthetic and antibiotic, using a single-sided incision at 2–3 days of age), and every piglet received an iron injection. The diet of piglets consisted of maternal milk and supplemental dry feed. During the lactation phase, the health status of the sows and piglets was good for both types of litters. Halfway through the lactation period, two trained technicians evaluated the sows' welfare condition based on ABMs, with all sows scoring grade 1 (Table 1), and behavioural indicators (Table 2), which showed a consistent engagement of sows in essential activities (resting, lactating or eating). The same evaluations were conducted for the litters, whose ABMs and behavioural profile were satisfactory and showed no differences between docked and undocked tail litters ($P > 0.10$). Piglets were weaned at 27 days of age, with an average weight of

Table 1

Health and comfort indicators for welfare assessment (number of subjects in each pen exhibiting the health and comfort indicator at the corresponding expression grade, relative to the total number of pigs in the pen).

Indicator	Description	Classification
<i>Dirty animals</i>	indicates the percentage of body surface covered in excrement	grade 1 is equivalent to 20 %, grade 2 is considered between 20 %–50 % and grade 3 is over 50 %
<i>Lame animals</i>	indicates presence of lameness	grade 1 corresponds to the absence of lameness, grade 2 refers to lameness that induces asymmetric movement and minimal load on the limb, grade 3 corresponds to lameness that induces the absence of load on the limb suffering or inability to walk
<i>Body lesions</i>	indicates presence and dimension of lesions on skin surface	classified as grade 1 if up to 4 in number and with a maximum dimension of 2 cm, grade 2 if between 5–10 in number, grade 3 if greater than 10 in number
<i>Tail lesions</i>	indicates presence or absence of tail wounds / lesion, with binary evaluation	grade 1 if absent, grade 3 if present in the form of bleeding, swelling and infections
<i>Ear lesions</i>	indicates presence or absence of ear scratch / lesion, with binary evaluation	grade 1 if absent, grade 3 if present in the form of bleeding, swelling and infections
<i>Enteric disorders</i>	only dysentery is evaluated	grade 1 absent, grade 2 presence of some liquid faeces, grade 3 all liquid faeces
<i>Respiratory disorders</i>	binary evaluation of presence/absence of disorders	grade 1 absence of coughing, sneezing or wheezing; grade 3 presence of the previous symptoms (even just one of the three)
<i>Bursitis</i>	evaluation of presence and dimension of sac-like cavity in correspondence of knees and elbow	grade 1 if absent, grade 2 if present on only one limb (1 large or more than one but small), grade 3 if present on one or both limbs, in greater numbers than 2 large or in a state of erosion
<i>Hernias</i>	evaluation of presence and dimension of inguinal hernias	grade 1 referred to no hernia, grade 2 to small hernias, grade 3 to large hernias that affect behaviour and/or touch the floor when the animal is in a quadrupedal position
<i>Rectal prolapses</i>	binary parameter: presence or absence of one or more layers of the rectum protrude through the anus	grade 1 if absent, grade 3 if present
<i>Straight tail (even with a docked tail, revealing the posture of the stumps)</i>	indicates stressful situations and the conditions of the flooring, density and in general to welfare	grade 1 if the tail is curled (or the stump is carried straight), grade 2 if the tail (or stump) is drooped, and grade 3 if the tail (or stump) is drooped and attached to the body
<i>Body Condition Score (BCS)</i>	binary parameter: evaluation of body condition score	grade 1 good condition, BCS 3–4; grade 3 evident state of malnutrition underlined by the prominence of the spinal processes, BCS 1–2

Table 1 (continued)

Indicator	Description	Classification
<i>Other conditions</i>	evaluated in a binary manner (grade 1 absent, grade 3 present)	grade 1 absent, grade 3 present Include dermatitis, neurological disorders (tremors, loss of balance and head turned on the sagittal plane), splay leg (hind legs spread apart), crowding (caused by low temperatures; it is considered such if a pig rests at least half of its body surface on another pig)

Table 2

Animal activities for behaviour assessment (number of subjects in each pen engaged in a specific behavioural activity, relative to the total number of pigs in the pen).

Activity	Description
<i>Enrichment use</i>	interaction/play with straw or other materials
<i>Structure use</i>	sniff, smell, lick or chew material in the pen
<i>Positive interactions</i>	any social behaviour between pigs that does not involve aggression, i.e. grooming, sniffing, nosing and licking
<i>Negative interactions</i>	bites, fights, headbutts
<i>Other activities</i>	essential behaviour, like eating, drinking, resting
<i>Fear of the humans</i>	any sort of panic generated by the presence of the observer, involved in constant piling up in the opposite part of the pens

7.1 ± 0.85 kg ($\mu \pm SD$).

At the beginning of the weaner stage, which lasted 56 days, two pens of pigs with undocked tails and two pens of pigs with docked tails were formed for each weaned band, with pigs divided by sex. In total, 295 pigs were divided into 16 pens, with four pens, one for each weekly band, assigned to each treatment combination (tail x sex). This included 151 undocked pigs, divided into four pens of castrated males (UC1 to UC4, totaling 72 pigs) and four pens of females (UF1 to UF4, totaling 79 pigs), and 144 docked pigs, divided into four pens of castrated males (DC1 to DC4, totaling 73 pigs) and four pens of females (DF1 to DF4, totaling 71 pigs). The length of the pigs' tails or stumps was measured twice, at the beginning and at the end of the weaner stage, using a slide caliper (Scienceware® Digi-Max™), and ranged from 9 cm to 13 cm in undocked pigs and from 3 cm to 5 cm in docked pigs.

Farm had forced ventilation with a burner heating system for the winter. Each pen featured slatted floors and enrichment materials, including one dispenser with strips of paper, two chains, and two wooden sticks placed at the edges of the pen. Pigs were raised at a stocking density of 0.30 (± 0.0153) m² per pig (18 ± 2 pigs per pen) in a temperature-controlled environment. Food was provided in hopper feeders (five feeding spaces; four/five piglets per hopper feeder) and the pigs were fed ad libitum with a commercial dry feed (pellets) based on cereals and hulled soybean meal (Table 3). Moreover, each pen was equipped with three nipple drinkers.

Table 3

Chemical composition (% of fresh weight) of the diets supplied to weaned pigs.

Nutrient	1–18 days	19–56 days
Crude Protein	17.00	16.00
Ether Extract	5.20	5.50
Crude Fibre	4.50	3.80
Ash	4.40	4.65
Calcium	0.50	0.50
Sodium	0.24	0.25
Lysine	1.28	1.35
Methionine	0.50	0.50

2.2. Assessment

2.2.1. Evaluation of welfare conditions and behavioural profile on the farm

The welfare conditions of the tested pigs were evaluated using a Qualitative Behaviour Assessment protocol, based on pre-existing ABMS procedures (AssureWel, 2015; Chiarelli, 2021; CReNBA, 2018; Welfare Quality®, 2009). Three levels of expression were defined for each health and comfort indicator as presented in Table 1.

The behavioural analysis involved observing the presence or absence of various animal activity, including interaction with enrichment materials and pen's structure, positive and negative social interactions between pigs, fear of humans, and other behaviour activities such as drinking, eating and resting (Table 2).

Visual examinations were carried out three times during the experimental period: at the beginning (7days), in the middle (28days), and at the end (56days) of the weaner stage.

The ABMs and behaviour assessments were performed by two trained observers. The training included six months of sessions at a local commercial pig farm before the start of the project (inter-reliability coefficient 0.90). Each pen was evaluated individually after morning feeding for 30 min. The first three minutes were used to encourage pigs to move by clapping hands and/or walking into the pen. This was followed by five minutes of quiet time to allow the pigs to calm down before observation began. The ABMs were recorded first. The observers stood in front of the pens for 10 min. and collaborated to assess each parameter of the protocol. After the ABM assessment, pig behaviour was recorded by assessing the specific activity each pig was engaged in, using instantaneous scanning. To assess fear of humans, one of the two observers walked into the pen and waited for approximately one minute to evaluate the escape response and the movement of individual animals. All measurements were taken consistently across all pens.

Group data were collected by recording, at each post-weaning time point, the number of subjects in each pen that exhibited the health and comfort indicator at the corresponding expression grade and engaged in a specific behavioural activity.

Animals moved to the sick pen due to damage from tail biting or other causes, such as growth and weight deficiencies or various diseases, were excluded from the experiment.

2.2.2. Hair sampling method and hormone analyses

The bristles were collected on day 56 of the weaner stage, at 12 weeks of age. Sampling was performed in the anatomical area between the ear and the shoulder using an electric clipper, which allowed for close shaving of the animal's skin. The collected bristles were assumed to retrospectively reflect hormone exposure as an integrated measure over the period from birth to four days before sampling. This lag time was calculated based on a bristle growth rate of 10.0 ± 0.24 mm/month and a follicle depth of 1.3 ± 0.04 mm, as suggested by Prims et al. (2019) for pigs of approximately the same age. Each sample was stored in a paper envelope at room temperature and protected from UV rays until processing by storing in a dark, dry place.

Afterwards, the bristle strands were washed and extracted for analysis following the protocol described by Bergamin et al. (2019). Washing with isopropanol is essential to minimise the risk of extracting steroids deposited on the surface of the bristles via sweat and sebum. The concentrations of CORT and DHEA(S) were measured using an in-house enzyme-linked immunosorbent assay (ELISA), as previously described for progesterone by Comin et al. (2005). Briefly, microplates were coated with anti-rabbit IgG antibody. After overnight incubation, the plates were washed five times with washing buffer. Aliquots of cortisol or DHEA-S standards, quality-control extracts, and bristle test extracts were added to the microplate wells. The cross-reactivity of the anti-cortisol antibody with other steroids was as follows: cortisol 100 %, cortisone 4.3 %, corticosterone 2.8 %, 11-deoxycorticosterone 0.7 %, 17-hydroxyprogesterone 0.6 %, dexamethasone 0.1 %, progesterone, 17-hydroxypregnenolone, DHEA-S, androsterone sulfate and

pregnenolone <0.01 %. The cross-reactivity of the anti-DHEA(S) antibody was 100 % for DHEA-S and 76.6 % for 5-androsten-3-ol-17-one (dehydroepiandrosterone, DHEA). Anti-cortisol and anti-DHEA(S) antibodies were diluted 1:32,000 and 1:80,000, respectively, in ELISA buffer and added together with the corresponding cortisol- or DHEA-S-peroxidase conjugates, diluted 1:6000 and 1:10,000, respectively. Plates were incubated overnight and then washed five times with washing buffer to remove unbound cortisol or DHEA(S). Bound conjugates were quantified by adding a chromogenic substrate. The plates were incubated for 30 min in darkness at room temperature (23 °C), and the reaction was stopped by adding 2 M H₂SO₄. Absorbance was read at 450 nm using a plate reader (EnSight Multimode Plate Reader, Perkin-Elmer Life Science, Boston, MA, USA).

The intra- and inter-assay coefficients of variation were 5.6 % and 13.4 % for cortisol, and 9.6 % and 12.2 % for DHEA(S), respectively. The assay sensitivities were 9.4 pg/mL for cortisol and 5.4 pg/mL for DHEA(S). The relationships between bristle cortisol and DHEA(S) concentrations and their respective standard curves were linear (parallelism), with correlation coefficients of $r = 1.00$. The regression equations were $y = 0.96x + 2.74$ for cortisol and $y = 0.99x + 0.40$ for DHEA(S). The mean recovery rates were 104.5 ± 4.0 % for cortisol and 111.9 ± 3.1 % for DHEA(S).

2.3. Experimental data and statistical analysis

Univariate and multivariate analysis were performed using SPSS (27.0.1) for Windows 10 (SPSS Inc., Chicago, IL) and Unscramble X 10.4 (CAMO software AS, Oslo, Norway). Data normality was assessed using the Shapiro-Wilk test. When necessary, hormonal data were normalised via log transformation before statistical analysis.

The experimental unit in the weaner stage was the pen group. The subjects of the observations were pigs, either castrated males or females, with intact tails (undocked) or shorter tails (docked). For each health and comfort indicator or behavioural activity, the percentage of subjects within each pen group that, at each time point of the weaner stage, exhibited the indicator at a specific expression grade or engaged in a particular activity was calculated. If no cases occurred, or if only one or two subjects on a whole were affected, the corresponding indicator was not analysed, presented, or discussed.

The experimental data regarding the effect of allostatic load were analysed on an individual basis, thanks to the identification of each subject, including tail condition and sex, verified during bristle collection.

Univariate analysis of variance considered the effect of the fixed factors Tail (docked vs. undocked) and Sex (castrated male vs. female). The evolution of health and comfort conditions or behavioural profile within the weaner stage was evaluated using a repeated-measures experimental design. The time point of the survey was treated as a within-group factor, while tail condition and sex were treated as between-group factors.

The tables present the mean and standard error of the mean of the untransformed data. A significance threshold of $P \leq 0.05$ was applied to all statistical tests, while observed values of $0.05 < P \leq 0.10$ were considered indicative of a tendency.

After individually analysing each indicator, activity, or hormonal parameter using ANOVA, their relationships were examined through multivariate analysis. To ensure consistency between variables, welfare and behavioural data were averaged across post-weaning time point within each pen group, while allostatic load data and resilience were averaged across individual pigs within each pen group. Subsequently, Partial Least Squares (PLS) method was applied to first assess the relationships between health and comfort indicators and behavioural activities, and then between these combined variables and hormonal parameters.

3. Results

3.1. Animals

At the beginning of the weaner stage, the average age, live weight, health, comfort and welfare conditions of piglets were homogeneous across pen groups.

Five pigs out of the 295 initially involved (approximately 1.7 %) were moved to the sick pen during the experimental phase, starting 28 days after weaning. These removals were not related to tail condition, sex, or their interaction ($P > 0.10$).

3.2. Health and comfort indicators

Enteric or respiratory disorders, bursitis, hernias, rectal prolapse or other pathological conditions are not presented, either because of their absence or because they involved only one or two subjects on a whole. Due to the lack of effects of tail condition or sex on body condition score (BCS) and dirtiness score, these results are not presented either. All pigs received grade 1 for BCS, indicating good health and nutritional conditions during the weaner stage. Pigs received a grade 2 for dirtiness (>20 % of their body surface covered by faeces, Table 2) sporadically, i. e., two undocked males in one pen on day 28, and four docked females in one pen on day 56. In all cases, the percentage of body surface receiving a grade 2 did not exceed 50 %.

Except for ear lesions, that were very limited in both tail condition groups, the other health and comfort indicators were affected by at least one experimental factor (Table 4). No lesions of any kind were observed during the first seven days after weaning. Regarding tail injuries, after the initial absence of lesions, undocked pigs began biting each other with noticeable frequency, leading to a peak tail lesion rate of 22.0 % halfway through the experimental period. Although the incidence slightly decreased thereafter, tail lesions persisted, still affecting 18.8 % of undocked pigs by the end of the weaner stage. In contrast, among docked pigs only a few cases of tail lesions were observed halfway through the weaner stage, reaching an incidence of 3.5 %. As a result, undocked pigs exhibited significantly higher tail lesions than docked pigs ($P = 0.02$). A significant interaction was observed between tail condition and sex ($P = 0.05$; Fig. 1), with the largest difference found in females, where lesion rates were 0.5 % in docked pigs compared to 22.4 % in undocked ones. No other significant effects of sex and interaction between sex and period on health and comfort indicators were observed and are therefore not presented.

The prevalence of pigs with more than four body lesions (i.e., severity grades 2 and 3) was significantly higher in those with undocked tails compared to docked tails ($P < 0.01$). The incidence of these lesions increased linearly with age ($P < 0.01$), following a slower progression in docked-tail pigs than in undocked-tail ones ($P = 0.01$; Table 4). A similar pattern was observed in the severity progression of body lesions (Fig. 2). From day 28 to day 56 post-weaning, the number of body lesions increased in both groups, with the proportion of pigs having >10 lesions eventually surpassing those with 5 to 10 lesions.

Compared with undocked pigs, a greater proportion of docked tails

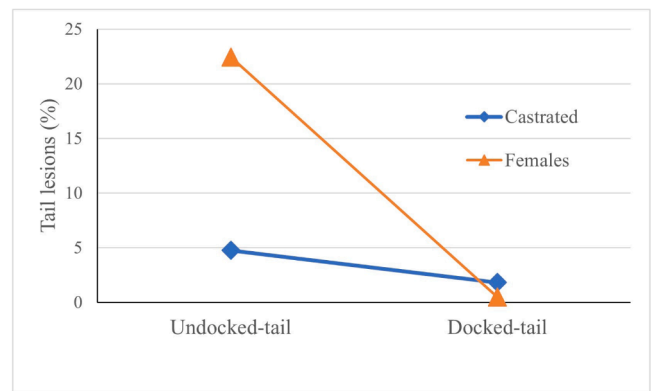


Fig. 1. Mean values of tail lesions during the weaner stage in castrated males (undocked and docked; four groups for each tail condition) and females (undocked and docked; four groups for each tail condition) pigs, expressed as the percentage within group of affected animals.

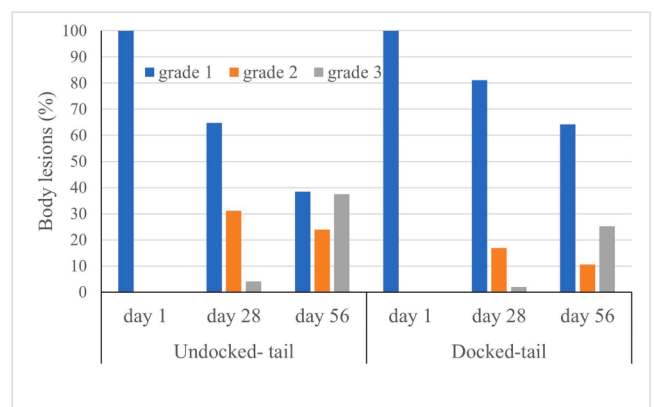


Fig. 2. Progression of body lesions severity (see Table 2) in castrated males (undocked and docked; four groups for each tail condition) and females (undocked and docked; four groups for each tail condition) pigs, during the weaner stage, expressed as the percentage of affected animals.

were scored as grade 1 for posture ($P < 0.01$; Table 4), which corresponds to either a curled undocked tail or a straight tail stump, both indicative of a pig's satisfactory emotional state. This tail posture was the predominant in pigs of both groups through the weaner stage. Docked pigs, characterized by a lower level of tail lesions, predominantly maintained a straight stump posture, increasing from 95.9 at the start to 99.3 % by the end of the experimental period (Table 4). In contrast, undocked pigs showed a different pattern: the peak of tail lesions midway through the weaner stage coincided with the lowest percentage of curled tails (47.6 %), following a significant quadratic trend over the weaner stage ($P = 0.04$; Table 4). Additionally, at the same time point, a notable proportion of undocked pigs (12.8 %) displayed tails

Table 4

Post-weaning evolution of health and comfort indicators as a function of tail condition and sex (% pigs per pen group).

	Docked (8 groups)			Undocked (8 groups)			SEM	P-value							
	Mean					Tail		Sex	Tail × Sex	Period		Tail × Period			
		Initial	Middle	Final	Initial					Middle	Final	Linear	Quadratic	Linear	Quadratic
Tail lesions	7.4	0.0	3.5	0.0	0.0	22.0	18.8	2.23	0.02	0.09	0.05	0.08	n.s.	0.08	n.s.
Ears lesions	0.8	0.0	2.9	0.0	0.0	1.4	0.7	0.38	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Body lesions*	25.2	0.0	18.9	35.8	0.0	35.2	61.5	1.67	<0.01	n.s.	n.s.	<0.01	n.s.	0.01	n.s.
Straight tail**	81.9	95.9	97.1	99.3	73.4	47.6	77.9	3.83	<0.01	n.s.	n.s.	n.s.	0.03	n.s.	0.04

* Body lesions: prevalence of pigs exhibiting severity grades 2 or 3.

** Straight tail: prevalence of pigs exhibiting severity grade 1.

tightly attached to the body (grade 3), indicating high stress (Fig. 3).

3.3. Behaviours

Except for the expression of negative interactions, neither tail condition, sex nor their interaction had an effect on any animal behaviour ($P > 0.10$; Table 5). Undocked females engaged in negative interactions at a higher rate than their docked counterparts (5.9 % vs. 1.5 %, respectively; $P = 0.05$).

The use of enrichment material in the pen followed a quadratic trend, peaking in the middle of the weaner stage ($P = 0.03$), while structure use showed a tendency towards a similar trend only in undocked pigs ($P = 0.09$). There was also a tendency for an increase in the percentage of pigs engaging in positive interactions ($P = 0.08$).

The percentage of fearful pigs is not presented, as the number of animals showing this behaviour was negligible. No effect of weaner stage period or its interaction with tail condition on other activities was found ($P > 0.10$).

3.4. Hormonal profiles

As shown in Table 6, sex had a significant effect on all hair hormones considered. Females showed higher CORT concentration than castrated males ($P < 0.01$), while castrated males had higher DHEA(S) values than females ($P < 0.01$). However, CORT concentration was also affected by the interaction between tail condition and sex ($P < 0.01$), with undocked castrated males and docked female presenting higher concentrations than docked castrated males (5.77 vs. 4.99 pg/mg; $P = 0.02$) and undocked females (6.59 vs. 7.38 pg/mg; $P = 0.03$), respectively.

The CORT/DHEA(S) tended to be higher in the hair of docked pigs compared with undocked pigs ($P = 0.06$), and it was greater in females ($P < 0.01$).

3.5. Relationship between indicators, activities and hormonal parameters

To investigate how pig behaviour and welfare change jointly as a function of tail condition and sex, a PLS regression model was used. Significant animal activities (Table 5) were considered response variables (Y), while significant health and comfort indicators (Table 4) served as explanatory variables (X). Weaner stage averages were used for both types of variables.

The PLS regression of behavioural variables (Y) on welfare indicators (X) produced the correlation loadings shown in Fig. 4 and the scores map depicted in Fig. 5. The first two PLS factors accounted for 87 % of the

variance in the X matrix but only 16 % in the Y matrix. Within the limits of the associated variability between the two sets of variables, ‘positive interactions’ between pigs, such as the ‘straight tail’ posture, fall on the negative side of factor 1, whereas ‘negative interactions’, such as ‘tail lesions’, are positioned on the positive side. Along factor 2, ‘use of enrichment’ and the ‘use of pen structure’ are positioned opposite to ‘body lesions’ (Fig. 4). Fig. 5 shows that all pen groups of docked pigs are located on the negative side of factor 1, while all but one pen group of undocked pigs fall on the positive side.

The relationship between hormonal response variables and visually assessed exploratory indicators -both welfare- and behaviour-related- was analysed using a PLS regression model applied to undocked pigs, which exhibited the highest prevalence of lesions. Fig. 6 presents the correlation loadings of X and Y variables, highlighting those with a contribution of approximately 70 % or higher to the two first factors. Meanwhile, Fig. 7 depicts the scores map of the experimental pig groups.

The first two PLS factors accounted for 67 % of the variance in the X matrix and 71 % in the Y matrix, with the latter showing a notable contribution from factor 1. Welfare and behavioral variables, considered together, loaded onto the first two factors with similar weight (32 % vs. 35 %), with a relative positioning that replicates previous observations. Specifically, along factor 1, ‘body lesions’ and ‘use of enrichment’ are in opposite position, as are ‘negative interactions’ and ‘tail lesions’ versus ‘straight tail’ posture along factor 2. Additionally, the response variables CORT/DHEA(S) ratio and DHEA(S) are also in opposite position and are located very close to ‘body lesions’ and ‘use of enrichment,’ respectively, along factor 1 (Fig. 6). Fig. 7 shows that all pen groups of undocked castrated males are located on the positive side of factor 1, while all but one pen group of undocked females fall on the negative side.

4. Discussion

Docked and undocked pigs exhibit different welfare conditions during the weaner stage. Specifically, pigs with undocked tails showed a significantly higher incidence of tail lesions compared to those with docked tails, both on average throughout the experimental period and at the peak of the phenomenon, which occurred midway through the stage. These findings align with a previous study, which reported that tail-biting behaviour tends to emerge as pigs grow and begin to fill the pen, typically around 42–49 days of age, as a result of the increased stocking density or decreasing pen space (Penny et al., 1981). While the negative relationship between space allowance and tail-biting has been highlighted in several studies, the interplay between stocking density, group size, and resource competition remains unclear (Valros, 2022; Wallgren et al., 2019).

The higher incidence of tail lesions was accompanied by a greater prevalence of body lesions in undocked pen groups compared to docked ones. In both groups, body injuries increased linearly throughout the weaner stage, reaching worrying levels by the end of the stage in undocked pigs. Similar to tail lesions, the increase in body lesions may be attributed to the progressive filling of the pen as the animals gain weight (Scollo et al., 2013).

Tail posture correlated with tail lesions and was influenced by tail condition (docked vs. undocked), with lowered tails observed more frequently in undocked pigs. This finding supports previous reports (Semrov and Patt, 2024; Wallgren et al., 2019; Wilder et al., 2020; Zonderland et al., 2009).

After a peak in the middle of the weaner stage, potentially driven by increased competition and stress in crowded conditions as pigs grow and individual space decreases, a general decline in the use of enrichment material was observed toward the end of the phase. This trend may be explained by the fact that pigs, like many animals, respond strongly to novel stimuli but quickly habituate with repeated exposure and their interest towards the new object declines (Zeng et al., 2023). Furthermore, as pigs mature, they might increasingly shift their focus from exploration toward more goal-directed activities, such as feeding and

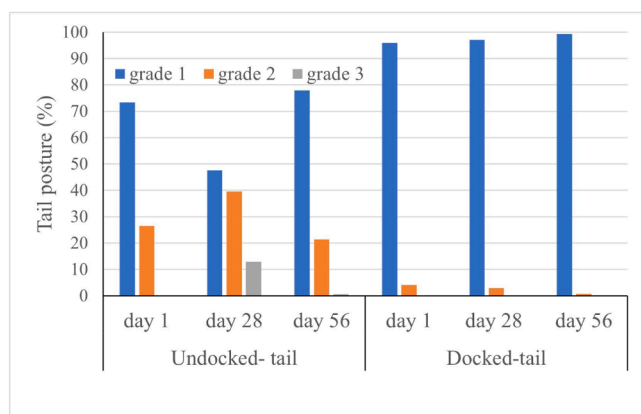


Fig. 3. Progression of postural expression levels of the tail or stump (see Table 2) in castrated males (undocked and docked; four groups for each tail condition) and females (undocked and docked; four groups for each tail condition) pigs, during the weaner stage, expressed as the percentage of animals exhibiting postural expression.

Table 5
Post-weaning evolution of behavioural profile as a function of tail condition and sex (% pigs per pen group).

	Docked (8 groups)			Undocked (8 groups)			SEM	P-value							
	Mean	Initial	Middle	Final	Initial	Middle		Final	Tail	Sex	Tail × Sex	Period		Tail × Period	
												Linear	Quadratic	Linear	Quadratic
Enrichment use	14.5	11.9	19.5	7.3	16.0	23.4	8.9	1.75	n.s.	n.s.	n.s.	n.s.	0.03	n.s.	n.s.
Structure use	14.9	22.8	6.15	12.3	16.1	18.7	13.1	2.34	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.09
Positive interactions	33.7	22.7	41.2	40.2	29.2	26.8	42.1	3.11	n.s.	n.s.	n.s.	0.08	n.s.	n.s.	n.s.
Negative interactions	3.5	1.4	1.4	5.2	4.8	4.7	3.8	0.60	n.s.	n.s.	0.05	n.s.	n.s.	n.s.	n.s.
Other activities*	33.4	41.3	31.7	35.0	33.9	26.5	32.1	3.79	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* Other activities: eating, drinking and resting.

Table 6
Hormonal profile of group of pigs as a function of tail condition and sex at the end of the weaner stage.

	Mean	Tail		Sex		SEM	P-value		
		Docked (8 groups)	Undocked (8 groups)	Castrated (8 groups)	Females (8 groups)		Tail	Sex	Tail × Sex
CORT*	6.18	6.19	6.18	5.38	6.99	0.095	n.s.	<0.01	<0.01
DHEA(S)**	16.2	14.7	17.8	18.2	14.2	0.476	n.s.	<0.01	n.s.
CORT/DHEA(S)	0.45	0.47	0.44	0.35	0.56	0.009	0.06	<0.01	n.s.

* CORT: cortisol.

** DHEA(S): dehydroepiandrosterone sulfate.

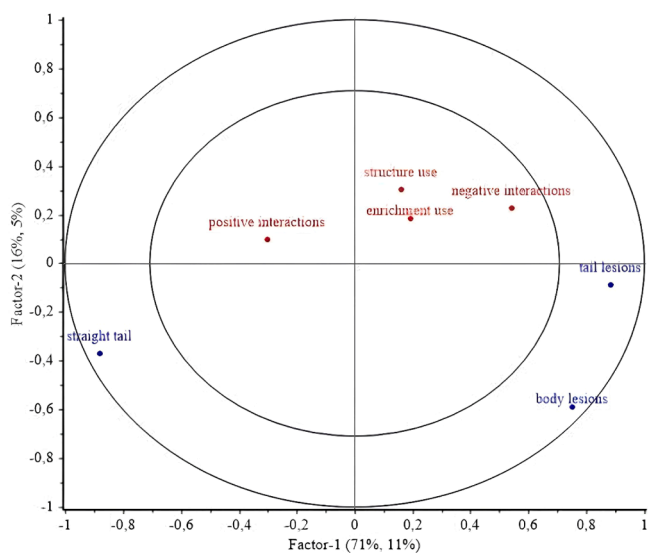


Fig. 4. Correlation loadings plot of the PLS regression model showing the relationship between animal activities (response variables in red) and health and comfort indicators (explanatory variables in blue) across 16 groups of castrated male and female pigs with undocked and docked tails during the weaner stage.

social interactions, leading to reduced interaction with enrichment material (van de Weerd and Day, 2009). The observed progressive linear increase in positive interactions between pigs, regardless of experimental group, might reflect a change in behavioural priorities accompanying their developmental stage.

However, pig social behaviour is not unidirectional, but rather multifaceted and context-dependent (D'Eath et al., 2014). Pigs engaged in both affiliative and antagonistic interactions, although the latter occurred at a much lower rate. As expected, in this experiment negative interactions such as biting, fighting, and headbutting were more frequent in pens where pigs sustained more injuries to both the tail and body. This condition characterized most of the undocked groups, particularly those consisting of female pigs. Conversely, the multivariate analysis indicated that pens in which pigs more frequently exhibited a

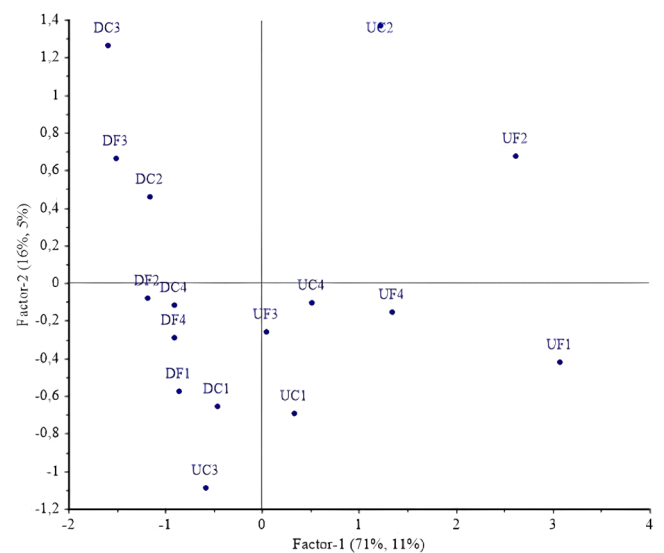


Fig. 5. Scores plot of the PLS regression model regarding the relationship between animal activities (response variables) and health and comfort indicators (explanatory variables), showing the distribution of 16 groups of castrated male (C) and female (F) pigs with undocked (U) and docked (D) tails during the weaner stage.

straight tail posture were associated with higher rates of positive interactions, a pattern predominantly occurring in the docked groups.

The underlying reason why female pigs are more prone to tail biting, mainly seen in undocked females, remains unclear (EFSA Panel on Animal Health and Welfare, 2007; Sinisalo et al., 2012). However, tail-in-mouth behaviour has been observed more frequently in females than in males, suggesting a higher predisposition among females to engage in tail biting (Schröder-Petersen et al., 2004). Given these behavioural tendencies, and considering that undocked pigs have longer and more accessible tails, it is possible that undocked females, in particular, are at greater risk of both exhibiting and being subjected to tail biting behaviour. Future studies could incorporate cameras and artificial intelligence to enable continuous behavioural monitoring of the animals, as highlighted in recent research (Arulmozhi et al., 2021;

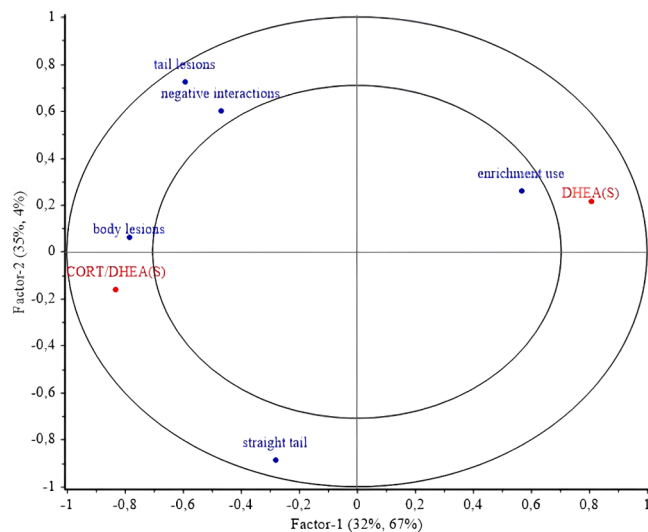


Fig. 6. Correlation loadings plot of the PLS regression model showing the relationship between hormonal parameters (response variables in red) and visual assessed exploratory indicators (both welfare- and behaviour-related; explanatory variables in blue) across height groups of castrated male and female pigs with undocked tails during the weaner stage.

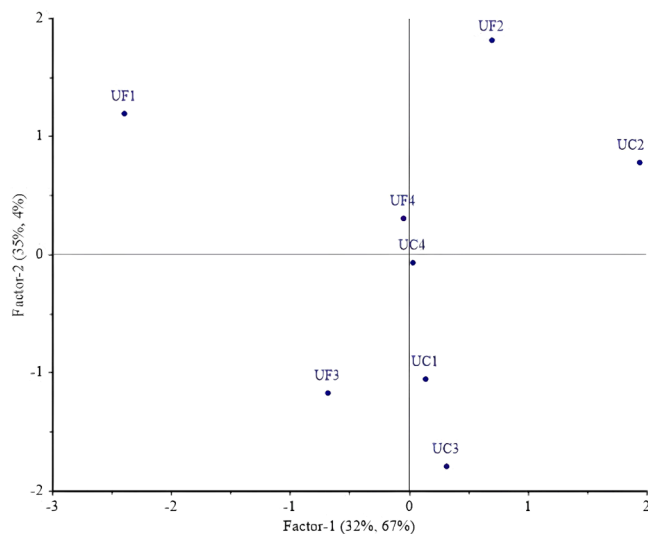


Fig. 7. Scores plot of the PLS regression model regarding the relationship between hormonal parameters (response variables) and visual assessed exploratory indicators (both welfare- and behaviour-related; explanatory variables), showing the distribution of height groups of castrated male (C) and female (F) pigs with undocked (U) tails during the weaner stage.

Xu et al., 2025). Such an approach may contribute to a more comprehensive understanding of health and comfort indicators, as well as behavioural patterns, thereby complementing the discrete observations obtained during specific sampling periods. This method could be particularly helpful in cases like ours, where more tail lesions were observed than negative interactions.

Hair CORT concentrations found in this study were similar to, or slightly lower than, those reported in previous studies (Casal et al., 2017; Levallois et al., 2024; Nannoni et al., 2018; Scollo et al., 2025). To our knowledge, data on hair DHEA(S) concentrations in weaned pigs are very limited. Scollo et al. (2025) recently reported DHEA(S) levels in the bristles of 3.5-month-old gilts that are consistent with those found in this study. The differences in hormonal concentrations between castrated males and females contrast with previous findings (Escribano et al.,

2023; Heimbürge et al., 2020; Montillo et al., 2020; Pollock et al., 2021), but align with the results of Bergamin et al. (2019). These sex-related differences may stem from various metabolic and behavioural factors. Notably, since DHEA plays a role in maintaining energy balance, castrated males may exhibit higher DHEA(S) concentrations, potentially offering protection against increased fat storage (Tagliaferro and Ronan, 2001).

The observed trend for higher CORT/DHEA(S) ratio, an indicator of the catabolic hormonal balance (Montillo et al., 2020; Qiao et al., 2017), observed in the bristles of undocked pigs suggests a greater activation of the hypothalamic-pituitary-adrenal (HPA) axis to restore homeostatic conditions, in response to body lesions, tail lesions and negative interactions. In a review on tail biting and related behaviours, D'Eath and colleagues (2014) highlighted that negative interactions can occur among group-housed pigs under stressful conditions. Thus, both visual observations and hormonal data indicate elevated stress levels in undocked pigs, likely due to the higher incidence of skin injuries and tail bites associated with intact tails. The availability and use of environmental enrichments continue to prove effective in enhancing pigs' resilience to stress, lowering blood CORT as shown by Parois et al. (2022). On the other hand, DHEA(S) has anti-glucocorticoid properties, it acts as an "anti-stress" steroid (Maninger et al., 2009) and is released concurrently with cortisol by adrenal glands in response to ACTH as a result of HPA axis activity to perform its neuroprotective role (Kamin and Kertes, 2017; Parker, 1999). Depletion of DHEA has been associated in humans with development of chronic disorders and experimental evidence strongly suggests that DHEA is closely linked to health maintenance (Tagliaferro and Ronan, 2001).

Future research should aim to compare farms that provide more space per animal than the minimum requirements set by European regulations, in order to reduce stocking density and potentially mitigate tail biting and other welfare issues. In addition to increased space allowance, further enrichment measures, such as greater availability of straw or other manipulable materials, should also be considered, as highlighted by Valros (2022). However, it is equally important that any proposed improvements are assessed not only for their potential benefits to animal welfare (Valros and Heinonen, 2015) but also for their practical and economic feasibility. As suggested by Menegon et al. (2025), adopting higher welfare standards must be balanced with realistic management practices and cost-effectiveness, to ensure that interventions can be successfully implemented at the farm level without compromising economic sustainability.

5. Conclusions

Tail integrity is a welfare target for European pig farming and is often considered a valuable indicator of positive on-farm pig welfare. This study found that weaned pigs with undocked tails had significantly more tail and body lesions than docked pigs, which also exhibited a higher incidence of straight tail posture, further highlighting the complex interplay of welfare components in shaping positive welfare states.

Although this study did not explore in detail the causes of this variability, it is important to emphasize that it was conducted in a commercial farm that ensures an acceptable level of welfare, in terms of structural and managerial requirements, according to the standards of the National Reference Center for Animal Welfare (CReNBA). Over time, tail and body injuries increased, likely due to decreased pen space and a decline in environmental enrichment use, as novelty faded and pigs increasingly shifted their focus toward social interactions.

The bristle hormonal profile provides insights into the activity of HPA axis, revealing sex-related differences and increased activation in undocked pigs. The intricate relationships among health and comfort indicators, behaviour, and hormonal responses in weaned pigs reinforce the need for comprehensive welfare monitoring. Avoiding reliance on stand-alone indicators while enhancing management strategies, such as increasing space allowance and environmental enrichment, is crucial

during this vulnerable production phase.

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Author agreement- livestock science

The corresponding author confirms the following statements on behalf of all authors:

- 1) that there has been no duplicate publication or submission elsewhere of this work
- 2) that all authors have read and approved the manuscript, are aware of the submission for publication and agree to be listed as co-author.

CRedit authorship contribution statement

Aloma Zoratti: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Isabella Pividori:** Writing – review & editing, Investigation. **Mirco Corazzin:** Writing – review & editing, Writing – original draft. **Gianluca Chiarelli:** Writing – review & editing, Writing – original draft, Investigation. **Luigi Faucitano:** Writing – review & editing, Writing – original draft. **Anna Zuliani:** Writing – review & editing, Writing – original draft, Conceptualization. **Edi Piasentier:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationship.

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