

Article

Salivary Cortisol Responses and Behavioural Reactivity of Lactating Sows During the Transition from Temporary Confinement to Free Movement in a Loose-Farrowing System

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Abstract

The placement of lactating sows in farrowing crates restricts movement and may limit the expression of species-specific behaviour. This study investigated physiological and behavioural responses of sows in loose-housed farrowing systems with temporary confinement. Seventy-one Landrace sows were temporarily confined in farrowing crates from entry into the farrowing unit until day 4 postpartum (p.p.), after which the crates were opened to allow greater freedom of movement. Saliva samples were collected twice daily on days 3, 5, 9, and 10 p.p. The Towel Test (TT) was performed on days 4 and 10 p.p. to assess behavioural responses to a novel stimulus. Cortisol concentrations differed significantly between sampling days, with higher concentrations on day 5 p.p. compared with days 3, 9, and 10 p.p. As this increase occurred after crate opening and declined thereafter, it suggests a transient physiological response to the change in housing conditions. Primiparous sows showed higher cortisol concentrations than multiparous sows. Behavioural responses in the TT were not significantly associated with cortisol concentrations, although higher TT scores were accompanied by numerically higher cortisol concentrations. These findings indicate that salivary cortisol is sensitive to short-term management-related changes, whereas behavioural responses provide additional information on individual variation. Combining physiological and behavioural indicators may improve welfare assessment in loose-farrowing systems.



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1. Introduction

In recent years, the welfare of farm animals in intensive production systems has become a growing public concern [1]. Farrowing crates, which restrict sows' movement and species-specific behaviour, are particularly debated due to their negative welfare implications [2,3]. Although originally introduced to reduce piglet mortality and improve

safety during farrowing [4], they are increasingly under ethical and legislative scrutiny. In several countries, including Germany, permanent confinement is being phased out [5].

Alternative systems such as loose-housed farrowing pens with temporary confinement aim to balance sow welfare with piglet survival and stockperson safety [6,7]. However, they may increase piglet crushing risk and complicate handling of unrestrained sows [8]. Sow behaviour, particularly human-directed responses, is therefore relevant for handling safety and welfare and is partly influenced by temperament and environment [9]. The first four days after birth represent the most critical period for piglet survival, as most pre-weaning mortality occurs during this time and is primarily attributable to crushing [10].

Stress in pigs arises from a wide range of environmental, social, metabolic, and management-related challenges and can negatively affect both animal welfare and performance [11,12]. Consequently, the identification of reliable welfare indicators is essential for the objective assessment of stress and welfare [13,14]. Cortisol is one of the most widely used biomarkers of the activation of the hypothalamic–pituitary–adrenal (HPA) axis and is therefore commonly used to assess stress responses in pigs [15,16]. As blood sampling may itself elicit an acute stress response and thereby influence cortisol concentrations [17], non-invasive glucocorticoid measurements have become valuable tools for welfare assessment in farm animals [18]. Salivary cortisol represents an established non-invasive alternative, reflecting the biologically active free fraction of circulating cortisol while avoiding the additional stress associated with blood collection [19,20].

Behavioural tests are widely used to assess individual differences in temperament, coping style, and fearfulness in pigs and therefore complement physiological measures of stress [21,22]. Among the most frequently applied tests are the Novel Object Test and the Back Test, which have been extensively used to characterize behavioural responses in piglets and growing pigs [23–25]. These tests typically require animals to be individually handled, restrained, or transferred to a separate test arena under standardized conditions. Such procedures are difficult to implement in lactating sows housed in commercial farrowing systems because of their large body size, confinement in farrowing crates, the presence of piglets, and the need to minimize disturbances during routine management. To address these practical limitations, Neu et al. introduced the Towel Test (TT), a standardized handling-like behavioural test designed to assess sow reactivity during routine management performed within the sow's home pen [26]. In the TT, a towel is suddenly thrown towards the sow's head while behavioural responses are recorded using a pre-defined scoring system. In contrast to conventional behavioural tests based on novelty or restraint, the TT is designed to evaluate sow reactivity under commercially relevant management conditions without requiring relocation of the animal or additional handling beyond routine procedures. Combining physiological and behavioural indicators may provide a more comprehensive evaluation of animal welfare than either approach alone, as glucocorticoid responses represent only one component of the complex adaptive processes underlying stress and welfare outcomes [22,27,28].

Although temporary confinement systems are increasingly implemented as alternatives to conventional farrowing crates, knowledge of the physiological responses of lactating sows during the transition from confinement to free movement remains limited. Previous research on temporary confinement systems has mainly focused on sow behaviour, fulfilment of behavioural needs, piglet survival, and production-related outcomes, whereas physiological responses during the transition from temporary confinement to free movement have received comparatively less attention [29]. Furthermore, whether behavioural reactivity assessed using the Towel Test is associated with physiological stress responses remains unclear. Changes in housing or management can induce short-term activation of the hypothalamic–pituitary–adrenal (HPA) axis as part of the adaptive response to al-

tered environmental conditions, even when these changes may ultimately improve animal welfare [11,12]. Therefore, repeated physiological measurements are required to characterize short-term adaptive responses and to distinguish them from potential indicators of impaired welfare.

The aim of this study was to evaluate the behavioural and physiological stress responses of lactating sows during the transition from temporary confinement to free movement in a loose-farrowing system. We hypothesized that the transition from temporary confinement to free movement would be accompanied by a transient increase in salivary cortisol concentrations, reflecting short-term physiological adaptation to the altered housing conditions, followed by a decline as sows acclimated to the new housing conditions. We further hypothesized that behavioural reactivity in the Towel Test would be positively associated with salivary cortisol concentrations.

2. Materials and Methods

2.1. Animals and Housing

The study was conducted on a nucleus farm (BHZP GmbH, Dahlenburg, Germany) in two batches (June–July 2018) with a four-week lactation period. A total of 78 purebred German BHZP Landrace sows (PRRS- and APP-free) were initially enrolled in the study. The expected farrowing date was defined as day 115 of gestation. Sows were expected to farrow naturally, and hormonal induction of farrowing was performed only when the expected farrowing date was exceeded. To minimize variation in physiological and behavioural responses associated with altered parturition timing, hormonally induced sows and those farrowing more than one day before or after the expected farrowing date were excluded. This approach limited variation in test days to ± 1 day, resulting in a final dataset of 71 sows (36 and 35 in two batches, respectively). Parity averaged 2.2 ± 1.4 (mean $\pm$ SD; range 1–7). Sows were grouped into PG 1 (first parity; $n = 30$), PG 2 (second parity; $n = 20$), and PG 3 (parity 3 and above; $n = 21$). In the first batch, PG1, PG2, and PG3 comprised 17, 9, and 10 sows, respectively, whereas in the second batch the corresponding numbers were 13, 11, and 11 sows, respectively.

Sows were routinely examined during the first three days postpartum for fever and purulent vulvar discharge and were treated when necessary. Sows that still exhibited clinical signs of disease on day 3 postpartum or required ongoing treatment would have been excluded from the study. Consequently, all 71 sows included in the final analysis were clinically healthy at day 3 postpartum, with no persistent fever, purulent culver discharge, or need for further treatment.

According to the German Animal Welfare Act, the study did not require approval by the competent authority because all procedures were part of routine husbandry. The study protocol was reviewed and approved by the institutional Animal Welfare Officer on 20 July 2018 (Ethic Code TVO-2018-V-67).

Sows were moved to the farrowing units one week before the expected farrowing date. Each farrowing unit consisted of 40 farrowing pens (2.7×2.1 m; Big Dutchman International GmbH, Vechta, Germany) equipped with farrowing crates with swing gates. The pens had partially slatted floors with a solid lying area and were not provided with bedding. Each pen was equipped with a hanging chain with a wooden block as enrichment material for the sow. The farrowing unit received natural daylight supplemented by artificial lighting, which was manually switched on and off by the stockpersons according to the natural photoperiod. Ambient temperature was not recorded but generally followed the prevailing outdoor summer temperatures. From entry into the farrowing unit until day 4 postpartum, sows were kept confined within the farrowing crates. On day 4 p.p. at 15:00, the swing gates were opened, allowing the sows greater freedom of movement. This

timing was chosen because the majority of piglet crushing occurs during the first few days after farrowing [10]. Water was available *ad libitum* via a nipple drinker positioned above the feed trough in the front of the pen. Feeding of the sows was provided via an automatic feeding system (Spotmix; Schauer Agtrontronic GmbH, Prambachkirchen, Austria). Each pen was equipped with a heated piglet nest, a piglet feeder, and a piglet nipple drinker outside the sow crate. Piglets were weighed, ear-tagged and litters were standardized to 14 piglets within 24 h postpartum when required.

The study followed a repeated-measures design to evaluate behavioural and physiological stress responses of lactating sows during the transition from temporary confinement to free movement. Stress responses were assessed using repeated measurements of salivary cortisol concentrations and behavioural reactivity in the Towel Test before and after the transition from temporary confinement to free movement. In addition, the influence of individual sow characteristics, including parity and behavioural reactivity, on physiological stress responses was evaluated. Salivary cortisol concentrations were determined on days 3, 5, 9, and 10 postpartum before and after the opening of the farrowing crate (day 4 p.p.). Behavioural reactivity was assessed using the Towel Test on days 4 and 10 postpartum. Figure 1 summarizes the experimental timeline.

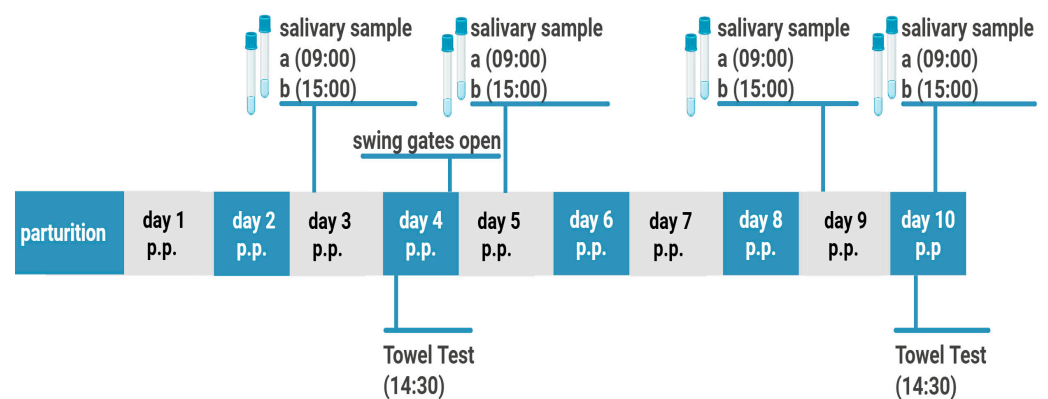


Figure 1. Experimental timeline including sampling times and behavioural assessments.

2.2. Saliva Cortisol

Saliva samples were collected on days 3, 5, 9 and 10 p.p. at 09:00 (a) and 15:00 (b), yielding 568 samples. All scheduled saliva samples were successfully collected, resulting in a complete dataset without missing cortisol measurements. Sampling was performed at two fixed time points to account for potential diurnal variation in cortisol secretion. The sampling times were maintained throughout the study to minimize variation associated with time of day. Sows were fed one hour prior to sampling but were not restricted from drinking. Samples were collected in the pens by two familiar veterinarians using a biocompatible synthetic fibre swab (Salivette Cortisol; Sarstedt, Nümbrecht, Germany). The swab was attached to a clamp and presented to the sow until it was saturated by chewing (~30 s). Visibly contaminated samples were discarded and repeated. The sows were not habituated to the sampling procedure prior to data collection. After collection, samples were kept cooled, centrifuged within one hour and stored at -20°C until analysis. Following completion of sampling, all samples were transferred to the University of Veterinary Medicine Hannover for cortisol analysis using an ELISA kit (ELISA DES6611; Demeditec Diagnostics GmbH, Kiel, Germany). The analytical sensitivity of the assay was 0.024 ng/mL. The assay was validated for pig saliva as follows: The intra-assay coefficient of variation (CV) was determined by analyzing a porcine saliva sample ten times within a single run, yielding a CV of 6.7%. The inter-assay CV was assessed by measuring a pooled sample across ten plates, resulting in a CV of 11.6%. Furthermore, linearity of

dilution was assessed by serial dilution of one porcine saliva sample and subsequent cortisol measurement, confirming assay linearity.

2.3. Behavioural Test

To assess the sow's individual behavioural reactivity, the Towel Test (TT) was performed as described by Neu et al. [26]. As the present study formed part of the experimental work in which the TT was established and evaluated, it was selected as the behavioural assessment method. While the sow was resting, an observer standing in front of the pen suddenly threw a towel (50 × 100 cm) towards the sow's head, and the sow's immediate response was scored in four categories: score 1 represented the sow showing no object-related reaction; score 2 a slight reaction, for example lifting her head; score 3 a moderate reaction, such as sitting up; score 4 a strong defensive or aggressive reaction. The test was performed by the same two trained observers who were involved in the development of the scoring system [26]. Prior to data collection, several preliminary assessments were conducted to synchronize scoring and ensure consistent application of the behavioural categories. Tests were performed at day 4 p.p. (TTd4; closed crates) and day 10 p.p. (TTd10; opened crates) at 14:30. This time point was chosen because it consistently corresponded to a resting period after afternoon feeding, ensuring standardized testing conditions across sows. Two sows did not show a resting period at the scheduled testing time on day 10 p.p. and were therefore excluded from TTd10 assessment (TTd10; $n = 69$). Due to the low frequency of scores 3 and 4, these categories were combined for statistical analyses.

2.4. Statistical Analysis

Analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Means and standard deviations were calculated with PROC MEANS. Normality was tested with PROC UNIVARIATE; cortisol data were right-skewed, indicating deviation from normality. Subsequently, a natural logarithmic transformation (ln) was applied. Residual diagnostics confirmed model assumptions. Results are primarily presented as ln-transformed least squares (LS) means. To facilitate interpretation on the original scale, back-transformed values are additionally reported as geometric means where appropriate.

Linear mixed models (PROC MIXED) were used to account for repeated cortisol measurements within individual sows. Sow was included as a random effect, and an unstructured covariance matrix was applied to model the correlation between repeated measurements. The covariance structure was selected based on model fit criteria, including Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC). Fixed effects included batch (2 levels), parity (3 levels, PG 1–3), time of day (2 levels, 09:00 and 15:00) and sampling day (4 levels; day 3, 5, 9 and 10 p.p.). Crate status (open or closed) was not included as a fixed effect because it was completely confounded with sampling day; all measurements before day 4 postpartum represented the confined condition, whereas all measurements after day 4 postpartum represented the open-crate condition. Therefore, the effect of crate opening could not be statistically separated from changes associated with postpartum time. Non-significant interactions between sampling day and time of day, as well as between sampling day and parity, were tested and subsequently removed from the final model. Separate models were fitted including TTd4 or TTd10 as fixed effects while retaining batch, parity, time of day, and sampling day as covariates to evaluate the association between behavioural reactivity and cortisol concentrations. The interaction between TT score and parity was tested but excluded from the final models due to lack of statistical significance. The association between TTd4 and TTd10 was assessed using Spearman's rank correlation. Pairwise comparisons of least squares means were adjusted

for multiple testing using the Tukey–Kramer method. A p -value < 0.05 was considered statistically significant.

3. Results

A total of 568 saliva samples were analyzed. The overall mean cortisol concentration was 5.18 ± 3.84 ng/mL (range: 0.75–26.00 ng/mL). Mean cortisol concentrations for each sampling time are presented in Table 1. Descriptive statistics are presented in Table 1, whereas model-adjusted LS means are shown in Figure 2.

Table 1. Salivary cortisol concentrations (mean $\pm$ SD) at each sampling time ($n = 71$ sows per sampling time).

Sampling Day	Cortisol Concentrations (ng/mL)	
	09:00	15:00
Day 3 p.p.	4.61 ± 3.57	3.84 ± 2.63
Day 5 p.p.	6.69 ± 4.10	7.34 ± 4.94
Day 9 p.p.	4.49 ± 3.11	4.90 ± 4.00
Day 10 p.p.	4.16 ± 1.66	5.39 ± 4.40

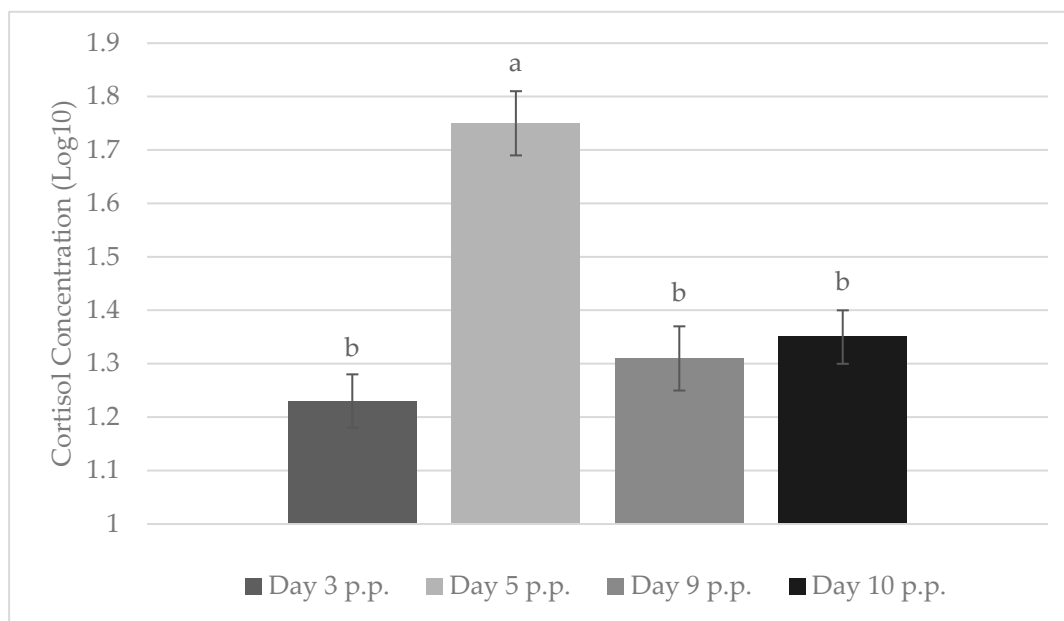


Figure 2. Salivary cortisol concentrations on different sampling days presented as ln-transformed LS-means ($\pm$ SE). Significant differences between days are indicated by different lowercase letters above bars ($p < 0.001$).

Cortisol concentrations differed significantly between sampling days ($p < 0.001$), whereas no effects of batch ($p = 0.428$) or time of day ($p = 0.726$) were detected. Estimated cortisol concentrations were highest on day 5 p.p. (geometric mean 5.77 ng/mL), followed by lower values on day 3 p.p. (3.43 ng/mL), day 9 p.p. (3.71 ng/mL), and day 10 p.p. (3.85 ng/mL) (Figure 2).

Parity had a significant effect on cortisol concentrations ($p = 0.017$). Primiparous sows showed higher estimated cortisol concentrations (PG1: 4.67 ng/mL) compared to second-parity sows (PG2: 3.80 ng/mL), with a tendency compared to PG3 (3.87 ng/mL; $p = 0.052$) (Figure 3).

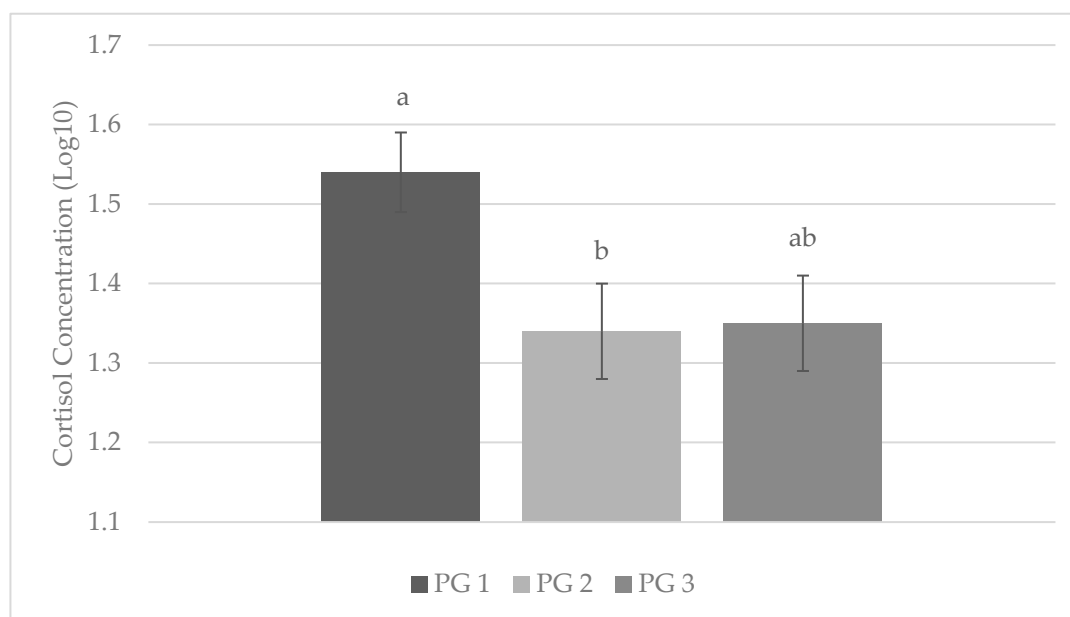


Figure 3. Estimated salivary cortisol concentrations for each parity group (PG) presented as ln-transformed LS-means ($\pm$ SE). Significant differences between PG are indicated by different lowercase letters above bars ($p < 0.05$).

No significant association was found between Towel Test scores and cortisol concentrations at either assessment (TTd4, $n = 71$: $p = 0.198$; TTd10, $n = 69$: $p = 0.660$). Mean cortisol concentrations across TT score categories are shown in Table 2. The distribution of Towel Test scores differed between day 4 p.p. and day 10 p.p., with a higher proportion of stronger reactions (scores 3–4) on day 10 p.p. (Table 3). Towel Test scores showed a moderate correlation between both time points ($\rho = 0.494$, $p < 0.001$).

Table 2. Cortisol concentrations for the respective Towel Test scores reported as ln-transformed LS-means ($\pm$ SE). Back-transformed geometric means are given in parentheses.

Cortisol Concentrations		
TT—Score	TTd4	TTd10
1	1.35 $\pm$ 0.07 (3.87 ng/mL)	1.39 $\pm$ 0.08 (4.02 ng/mL)
2	1.39 $\pm$ 0.05 (4.02 ng/mL)	1.35 $\pm$ 0.06 (3.86 ng/mL)
3 + 4	1.53 $\pm$ 0.08 (4.64 ng/mL)	1.43 $\pm$ 0.05 (4.16 ng/mL)

No significant differences were found.

Table 3. Percentage distribution of scores in the Towel Test (TT) on day 4 p.p. with closed farrowing crates and on day 10 p.p. (15:00) with open swing gates.

TT—Score	TTd4		TTd10	
	Sows (N)	%	Sows (N)	%
1	20	28.17	14	20.29
2	36	50.70	22	31.88
3 + 4	15	21.13	33	47.83
Total	71		69	

4. Discussion

The present study investigated behavioural and physiological stress responses in lactating sows housed in a loose-farrowing system with temporary confinement. A transient

increase in salivary cortisol was observed following the transition from confinement to free movement, with concentrations peaking on day 5 postpartum before declining on day 9 p.p. and 10 p.p. This temporal pattern is consistent with our hypothesis that the transition to free movement was associated with a short-term activation of the hypothalamic–pituitary–adrenal (HPA) axis, followed by physiological adaptation to the changed housing conditions. Cortisol secretion follows a circadian rhythm in pigs, with concentrations varying depending on time of day [30]. In the present study, however, time of day had no significant effect on salivary cortisol concentrations, indicating that the observed increase was unlikely to be explained by diurnal variation in cortisol secretion but was more likely associated with the management-related transition itself. These findings support the suitability of salivary cortisol as an indicator of short-term physiological responses to environmental and management-related changes.

The observed transient increase in cortisol concentrations is consistent with the concept that environmental and management-related challenges can induce short-term activation of the HPA axis as part of an adaptive stress response [11,12]. However, studies investigating cortisol responses in different farrowing systems have reported variable findings, with differences likely related to variation in housing design, management procedures, and the degree of environmental change [31–34]. Increased physical activity after crate opening has been suggested as one possible explanation for elevated cortisol concentrations in loose-housed sows [34]. Consequently, the observed cortisol increase should not necessarily be interpreted as evidence of impaired welfare but may also reflect the physiological demands associated with increased locomotion and exploration of the newly available space. However, because crate opening coincided with advancing postpartum time in the present design, the relative contribution of increased locomotion, environmental change, and natural postpartum endocrine variation cannot be determined. Differences between studies are likely related to variation in housing design, the degree of environmental novelty, management procedures, and behavioural activation, all of which may influence cortisol secretion independently of longer-term welfare status.

Alternative indicators of longer-term stress, such as heart rate variability [35] or hair cortisol [36,37], have produced inconsistent findings regarding the welfare consequences of different farrowing systems. Together these observations underline that no single physiological parameter is sufficient to comprehensively assess animal welfare and that cortisol concentrations should be interpreted within the broader behavioural and management context.

Parity significantly influenced salivary cortisol concentrations, with primiparous sows exhibiting higher concentrations than multiparous animals. This finding could indicate that younger sows are more sensitive to the physiological and environmental challenges associated with farrowing and early lactation or are less habituated to these events than older sows. However, parity is closely associated with several biological factors, including litter size, farrowing duration, and maternal experience, all of which may influence HPA-axis activity and therefore cannot be excluded as contributing factors in the present study. Previous studies have likewise reported inconsistent effects of parity on cortisol secretion. While some authors observed decreasing basal cortisol concentrations with increasing age [38,39], possibly reflecting habituation to repeated reproductive cycles, others reported higher stress indicators in older sows [34], potentially associated with larger litters and prolonged parturition. Together, these findings suggest that parity-related differences in stress responsiveness are multifactorial and likely depend on both physiological and management-related factors.

Behavioural reactivity assessed using the Towel Test was not significantly associated with salivary cortisol concentrations at either assessment. Although sows with higher TT

scores tended to exhibit numerically higher cortisol concentrations on day 4 postpartum, this tendency was not statistically significant. The absence of a significant association suggests that behavioural reactivity measured by the Towel Test and salivary cortisol reflect different aspects of the stress response under the conditions of the present study.

Interestingly, behavioural responses changed over time. On day 10 postpartum, a greater proportion of sows showed strong behavioural reactions in the Towel Test than on day 4 postpartum. This observation is consistent with previous findings reporting increased behavioural responsiveness in loose-housed sows compared with confined sows [40]. However, because housing conditions and sampling day were inseparable in the present study, the increased behavioural reactivity cannot be unequivocally attributed to the opening of the farrowing crate alone. Postpartum behavioural changes, increasing maternal activity, or recovery from parturition may also have contributed to the observed differences between test days.

The absence of a significant association between behavioural reactivity and salivary cortisol concentrations suggests that these measures may reflect different components of the stress response rather than indicating the absence of biologically meaningful individual differences. Glucocorticoids are considered proxy indicators of animal welfare, and their interpretation depends on the type, duration, and context of the challenge rather than representing a direct measure of the welfare status itself [28]. Accordingly, behavioural and physiological responses may be regulated by partly independent mechanisms and do not necessarily change in parallel under all conditions. Thus, behavioural tests and endocrine measures should be regarded as complementary approaches that provide insights into different aspects of stress responsiveness.

Individual differences in coping style may partly explain the observed variation in behavioural and physiological responses. Proactive and reactive animals have been reported to differ in both behavioural characteristics and HPA-axis responsiveness [41–43]. However, differences in endocrine responses between coping styles are not always consistent and may depend on the characteristics and context of the stressor [41–43]. Consequently, the absence of a significant association in the present study does not necessarily indicate that behavioural reactivity is unrelated to physiological stress but rather suggests that both measures reflect different components of the animal's response to environmental challenges.

The moderate repeatability of Towel Test scores between days 4 and 10 postpartum indicates a certain degree of consistency in individual behavioural responses despite the change in housing conditions. This observation agrees with previous studies demonstrating that behavioural traits in pigs are partly stable over time and show moderate heritability [24,37]. Moreover, behavioural characteristics have been linked to maternal behaviour and piglet survival [44,45], suggesting that behavioural assessments such as the Towel Test may provide relevant information beyond physiological stress measurements alone.

Salivary cortisol concentrations in the present study responded to the transition from temporary confinement to free movement, showing a transient increase followed by a decline during subsequent adaptation. However, cortisol responses are influenced by multiple factors, including physical activity and environmental changes, and should therefore be interpreted within the broader context of animal responses. The absence of an association between Towel Test scores and cortisol concentrations suggests that behavioural reactivity and endocrine responses may represent partly independent components of stress responsiveness.

Several limitations should be considered when interpreting the findings. First, the study did not include a parallel control group of sows that remained continuously confined throughout the lactation period. Therefore, the observed increase in salivary cortisol con-

centrations after crate opening cannot be unequivocally attributed to the transition from temporary confinement to free movement. In particular, the cortisol peak observed on day 5 postpartum may partly reflect physiological changes associated with the normal course of early lactation rather than solely a response to the change in housing conditions. However, the repeated-measures design allowed the assessment of individual cortisol trajectories over time and provided insights into physiological changes occurring during this management transition. A related limitation is that crate status was completely confounded with postpartum day in the present study. Because all measurements before day 4 postpartum were obtained while sows were confined and all subsequent measurements were obtained after crate opening, the effects of housing transition and physiological changes associated with advancing lactation could not be statistically separated. Consequently, the observed cortisol changes after crate opening should be interpreted as an overall response occurring during this management transition rather than as a direct causal effect of crate opening alone. Future studies including a continuously confined control group or staggered opening times would be valuable to disentangle the effects of housing transition from the natural physiological trajectory after farrowing. The study was conducted on a single commercial nucleus farm during the summer period, which may limit the transferability of the results to other production conditions. Furthermore, physical activity was not quantified, preventing differentiation between increased locomotion and other potential contributors to cortisol activation after crate opening. In addition, piglet mortality during the experimental period was not recorded, and therefore no comparison with mortality data from conventional farrowing systems or non-temporary confinement systems could be performed. Future studies should include standardized recording of piglet survival to allow a more comprehensive evaluation of the potential effects of loose-farrowing systems on piglet welfare outcomes. Finally, the study focused on the short-term transition period, and longer-term adaptation to loose-farrowing conditions requires further investigation. Future studies combining behavioural assessments, physiological indicators, and activity measurements over extended observation periods may help to better characterize individual adaptation strategies and welfare outcomes in loose-farrowing systems.

5. Conclusions

This study demonstrated that the transition from temporary confinement to free movement in a loose-farrowing system was associated with a transient increase in salivary cortisol concentrations, followed by a return to lower levels within the following days. This pattern indicates a short-term physiological response to the change in housing conditions rather than evidence of prolonged activation of the stress response. Primiparous sows showed higher cortisol concentrations than multiparous sows, suggesting that parity contributes to individual differences in physiological responsiveness.

Behavioural reactivity assessed using the Towel Test was not associated with salivary cortisol concentrations, although individual behavioural differences were consistent over time. These findings indicate that behavioural and physiological measures provide complementary information on sow responses to changing housing conditions. A combined assessment approach may therefore improve the evaluation of welfare consequences associated with transitions to loose-farrowing systems.

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Institutional Review Board Statement: The animals of this study were kept in accordance with the European Directive 2008/120/EC and the corresponding German national law (Tierschutzgesetz (Animal Protection Act)) and Tierschutz-Nutztierhaltungsverordnung (Animal Protection—Livestock Ordinance). The concept of the study was reviewed and approved by the Animal Welfare Officer of the University of Veterinary Medicine Hannover, Hannover, Foundation on 20 July 2018. The Ethic Code of the respective study is TVO-2018-V-67. In compliance with European Directive 2010/63/EU Article 1 5.v(f), the examination did not involve any invasive treatment, and no negative effects on the animals were expected.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy reasons related to BHZP GmbH.

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Conflicts of Interest: Author Barbara Voß was employed by the company BHZP GmbH. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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