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Sow free farrowing behaviour: experiential, seasonal and individual variation

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Abstract

Although sow confinement at farrowing is inherently stressful, farrowing crates remain in widespread commercial use. Sows adapt to their environment, however adaptation may be counter-productive if the farrowing system changes. The current study observed the behaviour of second parity sows throughout farrowing in a straw pen system to determine if their previous farrowing experience, in either the same pen system (n=11) or a temporary confinement crate system (n=11), affected current nest-building, farrowing and nursing behaviour. Data were analysed using PROC MIXED, with sow ID as the repeated subject. Sows which previously farrowed in pens tended to have a higher pre-partum peak nesting intensity ($P = 0.081$), and throughout parturition exhibited increased lateral lying ($P < 0.01$), decreased ventral lying ($P < 0.001$), decreased sitting ($P < 0.01$) and a decreased frequency of dangerous posture changes ($P < 0.05$). Post-partum, sows that previously farrowed in pens had a lower percentage of sow-terminated nursing ($P < 0.01$), a longer average duration of successful nursing bouts ($P < 0.05$) and a lower frequency of sow-terminated nursing bouts ($P < 0.001$). Seasonal effects were also seen in this naturally-ventilated system, both pre- and post-partum, with autumn/winter farrowings associated with more pre-partum nesting ($P < 0.01$), a higher pre-partum peak nesting intensity ($P < 0.05$), a longer average duration of successful nursing ($P < 0.05$) and a higher percentage of nursing bouts ending with piglets asleep at the udder ($P < 0.05$) than in the spring/summer. Individual variation in pre-partum nesting behaviour was associated with differences in parturient and post-partum behaviours. The results show that the prior experience of confinement, or a change of farrowing system, significantly affects sow farrowing behaviour in free farrowing pens, which may compromise the welfare of both sows and piglets.

Keywords: pig, nest-building, maternal behaviour, previous experience, straw pen

1. Introduction

Research has demonstrated that prolonged confinement of the farrowing sow causes physiological stress and compromises sow welfare (Jarvis *et al.*, 2006), however farrowing crates remain the predominant system used throughout farrowing and lactation on commercial indoor pig farms (Baxter & Edwards, 2016). Although three countries have banned the use of farrowing crates (Norway, Sweden and Switzerland), in other countries concerns about increased piglet mortality in free farrowing systems remain (e.g. the UK, FAWC, 2015). Whilst the primary reason for sow confinement is to reduce the risk of piglet crushing (FAWC, 2015), some surveys of commercial farms have found no significant benefit of using crated farrowing systems in reducing overall piglet mortality (Weber *et al.*, 2009; KilBride *et al.*, 2012).

Whilst temporary confinement systems, whereby the sow is confined in a crate from entry into the farrowing house until approximately 2-7 days post-partum, provide a compromise between the requirements of farmers and livestock, the sows' behavioural need to perform pre-partum nest-building behaviours is rarely met in such systems. Pre-partum, confined sows without access to suitable substrates will still attempt to perform nest-building behaviour and show increased physiological stress responses (Lawrence *et al.*, 1994; Damm *et al.*, 2003), which may result in a prolonged farrowing duration (Wülbers-Mindermann *et al.*, 2002; Oliviero *et al.*, 2008) and increased savaging of piglets by gilts

(Jarvis *et al.*, 2004). Provision for pre-partum nest-building has further benefits for the new-born piglets, being associated with improved maternal responsiveness to piglet distress calls (Herskin *et al.*, 1998; Thodberg *et al.*, 2002a), enhanced piglet serum IgG and IgM levels from increased colostrum intake (Yun *et al.*, 2014) and reduced pre-weaning piglet mortality (Cronin & Van Amerongen, 1991).

Although sow pre-partum nesting behaviours are affected by the immediate farrowing environment, including seasonal climatic variations (Jensen, 1989), behaviour also develops over successive parities as the sow adapts to repeated housing in the same system (Damm *et al.*, 2003; Jarvis *et al.*, 2001; Thodberg *et al.*, 2002a). This may also be true post-partum, as the maternal behaviour of previously crated and penned sows remained dissimilar when subsequently housed in the same farrowing system (Thodberg *et al.*, 2002b), demonstrating that prior confinement may impact the development of sow farrowing behaviour. However, no differences in pre-partum or maternal behaviours were observed amongst outdoor sows which were previously housed outdoors or in indoor pens (Wülbers-Mindermann et al., 2015). Whilst the majority of commercial sows return to the same farrowing system throughout their reproductive life, some farms move sows between farrowing systems in consecutive parities, especially as interest in alternatives to conventional farrowing crates increases and new systems are trialled or adopted. However, a change of farrowing system is postulated to be detrimental for sow welfare (RSPCA, 2016), may disrupt the appropriate adaptation of sow farrowing behaviours to the farrowing system over successive parities and ultimately result in increased pre-weaning piglet mortality (King *et al.*, 2018).

The purpose of the current study was to investigate the effect of the first parity farrowing system, either a temporary confinement crate system or straw-based free farrowing pen, on the pre-partum nesting, farrowing and post-partum nursing behaviour during the second parity when all sows were housed in the same straw-based free farrowing system. As the farrowing system used was in a naturally ventilated building and thus subject to seasonal temperature fluctuations, behavioural observations were conducted throughout the year to determine any seasonal variation in sow farrowing behaviours. The effect of individual differences in pre-partum nest-building behaviour on partum and post-partum behaviour was also explored.

2. Materials and methods

2.1. Animals and dry sow management

Data were collected on a commercial pig breeding unit in the north east of England. The farm consisted of 1300 Camborough (Genus PIC, Basingstoke) breeding gilts and sows, bred with Hampshire semen collected on-site for artificial insemination. During gestation, all animals were kept in straw pens in groups according to body size. Animals were generally moved into the farrowing accommodation one week before their expected farrowing date.

2.2. Farrowing sow housing and management

During farrowing and lactation, second parity sows were housed in a straw-based free farrowing pen (Figure 1a), whilst for their previous farrowing they had either been housed in the same farrowing system (pens) or a temporary crate system (360s; 360º Freedom Farrower®, Midland Pig Producers, Burton-on-Trent; Figure 1b and see King *et al.*, 2018 for images and full details of this system).

Pens were in rows of individual units, each consisting of a 2.30m x 1.20m indoor nest area with adjacent 2.30m x 0.70m separate covered piglet creep area and access to a 2.55m x 2.00m outdoor run (Figure 1a). Pens had a solid concrete floor throughout, whilst the nest area contained farrowing rails and piglet protection bars across three sides to reduce piglet crushing risk. The nest area contained 5kg of long straw from the day of sow entry into the farrowing system, whilst the entire creep floor was covered in wood shavings. The pens had no ambient temperature controls, however a 400w electric heater was located at one end of each creep, these being individually switched off three to five days post-partum. Pens were routinely cleaned out weekly with straw and wood shavings replenished. Pre-partum, additional straw or wood shavings were added to nests when required and soiled straw was removed and replenished post-partum.

The 360s comprised of a stainless steel crate (2.50m x 0.90m when closed, 2.50m x 1.60m at sow shoulder height when opened) within a 2.50m x 1.80m pen (Figure 1b). The 360s had plastic slatted flooring with a solid panel containing drainage slots in the sow lying area plus a 1.80m x 0.40m heat pad to one side of the crate. Two parallel vertical bars were positioned at the rear of the crate for additional piglet protection. The 360s crates were closed from sow entry into the farrowing house until approx. ten days post-partum, with no nesting materials provided. Buildings containing 360s were kept at 22 ± 1°C, with the additional heat mat along one side of each pen starting at 36°C and reducing to 30°C by weaning. Room temperature was gradually reduced automatically to 18 ± 1°C by day ten post-partum and to 16 ± 1°C by weaning.

2.3. Farrowing sow and piglet husbandry

Sows were hand-fed once daily in the morning, onto the floor of the nest area in straw pens or troughs in the 360s, until all sows in a building had farrowed, after which sows were fed twice a day (diet composition: 15.98% CP, 13.69 MJ DE/Kg). Feed was gradually increased from 1kg to 6kg per sow per day throughout lactation, whilst water was provided ad libitum, either from drinkers above the trough in the 360s or from a floor trough in the outdoor area of the pens (Figure 1a and 1b). A handful of creep feed (Primary Diets, AB Agri Ltd, Peterborough; followed by Flat Deck, A-One Feed Supplements Ltd, Thirsk) was provided once daily on the floor in all systems from approx. ten days of age until weaning.

In accordance with veterinary recommendation for this farm, piglets were tail docked, teeth clipped, and injected with 1ml of Gleptosil (Ceva Animal Health Ltd, Amersham) and 0.5ml of Betamox (Norbrook Laboratories Ltd, Newry) within 24 hours of birth. Placenta and deceased piglets were also removed at this time, and live litter size was equalised for both piglet number and size by cross-fostering piglets of a similar age. The farm's management routines included piglet fostering, which occurred throughout lactation as necessary to ensure piglet and litter sizes remained similar.

2.4. Experimental design

The behaviours of 22 sows were recorded during their second parity when all sows farrowed in straw pens, using a 2x2 factorial design for the previous farrowing system (pens or 360s) and current season (spring/summer = Apr-Sep, autumn/winter = Oct-Mar) to produce four combination groups – pens-spring/summer (n=6), pens-autumn/winter (n=5), 360s-spring/summer (n=5) and 360s-autumn/winter (n=6). This subgroup of sows was selected for behavioural observation from our preceding larger study investigating the effect of the previous farrowing system on piglet mortality (King *et al.*, 2018).

2.5. Data collection

Behavioural observations were recorded during the period from January 2015 to July 2016. CCTV cameras (Gamut Professional Sony Effio E Bullet CCTV Camera 700 TV Line, 15m Infrared Night Vision (Gamut, Open24 seven Ltd, Bristol, UK)) were installed above each pen to observe the indoor nest area only. Cameras recorded continuously from two days before until two days after farrowing. From the video recordings, time of birth of first piglet (BFP) was identified, with the period of analysis for nesting behaviour comprising the 24 hours before BFP, farrowing behaviour analysis from the BFP until the last liveborn piglet, and the post-partum nursing observation occurring from 24 hours until 48 hours after the birth of the last live born piglet. Video data were analysed for all 22 sows during the nesting period, however three sows were excluded from some parts of analysis due to spending a significant proportion of time out of view in the outside area (two sows during parturition: one from each of the previous systems; one sow post-partum: previously in the 360s).

Pre-partum nesting analysis was performed using five minute scan sampling for the 24 hours before the birth of the first piglet (BFP), with sow postures (lateral lying, ventral lying, standing, sitting, out of sight (outside)) and nesting behaviours (straw-directed, pen-directed, turning around in nest, none) recorded as percentages of total pre-partum observations. Additional nesting behaviour measures were calculated using adapted measures from Thodberg *et al.* (2002a; Table 1). The first 60 minutes (12 observations) after feeding were eliminated from analysis, so as not to confound feeding with straw rooting behaviour.

Measures during farrowing were adapted from Thodberg *et al.* (2002a), using continuous recording. Total farrowing duration was from the first until the last born piglet, excluding any final stillborn piglet in a litter. From this, the early (first three piglets), late (last three piglets) and overall mean inter-piglet birth intervals were calculated. Frequency of dangerous posture changes throughout parturition (stand-to-lie, sit-to-lie, rolling, total), latency to the first posture change after BFP and the frequency of posture changes during the early birth interval (first three piglets) were recorded, whilst the percentage of duration of parturition in each posture (lateral lying, ventral lying, standing or sitting) was also recorded.

Post-partum, total duration in each posture and frequency of dangerous posture changes were recorded in the same manner, and also included the total duration and frequency of the sow going into the outside run. Descriptions of nursing behaviour are shown in Table 1. The frequency and average duration of sow-terminated nursing, successful nursing and all nursing bouts were calculated, as were the mean time interval between successful nursing bouts, and the percentage of all nursing bouts which were sow-terminated, successful, occurring with the udder facing the creep and ending with piglets asleep at the udder.

2.6. Statistical analyses

Analyses were performed using PROC MIXED in SAS 9.4. Models for describing nesting behaviour included the fixed effects of previous system (pen or 360) and the current season (spring/summer = Apr-Sep, autumn/winter = Oct-Mar). The base models for farrowing and nursing behaviours included individual sow ID as the repeated subject, the fixed effects of previous farrowing system and season and the six measures of pre-partum nesting behaviour as continuous variables. Variables were eliminated in a step-wise manner, with all final models including variables of $P < 0.10$. Only significant effects ($P < 0.05$) are presented for continuous variables, whereas tendencies ($P < 0.10$) are also discussed for fixed effects.

Farrowing models for duration measures included the base model plus total born litter size as a continuous variable. Farrowing models for postures and posture changes included the base model plus total farrowing duration as a continuous variable. Models for latency to first posture change after BFP and total posture changes during the early farrowing interval included the duration of the early farrowing interval instead of the total farrowing duration.

Post-partum models for nursing behaviour (excluding percentage of nursings with the udder facing the creep and percentage of nursings where piglets fell asleep at the udder), posture changes and total duration of postures included the base model plus total born litter size as a continuous variable. The model for the percentage of nursings where the udder faced the creep included the base model, total born litter size and creep location as a fixed effect (left or right), whilst the model for the percentage of nursings where piglets fell asleep at the udder included the base model plus total born litter size and the frequency of both successful and sow-terminated nursing bouts as continuous explanatory variables.

3. Results

3.1. Nesting behaviour

Nesting peak intensity tended to be affected by the previous farrowing system ($P = 0.081$), being higher for sows that previously farrowed in the pens (8.09 ± 0.52) than the 360s (6.73 ± 0.52). The last standing bout latency before BFP also tended to be affected by the previous farrowing system ($P = 0.084$), being longer for sows which previously farrowed in the pens (47.7mins ± 10.4) than the 360s (20.9mins ± 10.4). No effects of the previous farrowing system were observed for the percentage of observations in each posture, or on the timing of peak nest building, timing of the last nest building, or the last posture change latency before BFP. A number of pre-partum postures and nesting activities were affected by the current season, with significant effects displayed in Table 2.

3.2. Farrowing behaviour

The significant associations of the six measures of pre-partum nesting behaviour with farrowing duration measures, percentage of time in different postures and frequency of dangerous posture changes are shown in Table 3. The most significant associations were that with increasing time to BFP after the last nesting bout, latency to first posture change after BFP increased (+28.2mins ± 5.2; $P < 0.001$), whilst an increased percentage of pre-partum observations performing nesting behaviours was associated with an increased duration of ventral lying (+1.23mins ± 0.30; $P = 0.001$) and a decreased duration of lateral lying (-1.65mins ± 0.40; $P < 0.001$) during parturition.

3.2.1. Duration of farrowing

Total farrowing duration increased with increasing total born litter size (+26.8mins ± 11.6 per piglet; $P < 0.05$), whilst the early farrowing interval decreased with increasing time since the last pre-partum nesting bout (-6.52mins ± 3.10 per additional hour of latency; $P = 0.05$). No other variables were found to affect measures of farrowing duration.

3.2.2. Postures during farrowing

The effect of the previous farrowing system on the percentage duration of farrowing by posture is shown in Figure 2. Sows that had previously farrowed in the pens spent an increased percentage of farrowing lying laterally ($P < 0.01$) and a decreased percentage of farrowing spent lying ventrally ($P < 0.001$) or sitting ($P < 0.01$) than sows which previously farrowed in the 360s. The percentage of time spent sitting decreased ($P < 0.01$), whilst the percentage of time spent standing also tended to decrease ($P = 0.068$), with increasing total farrowing duration.

3.2.3. Frequency of dangerous posture changes

The effect of the previous farrowing system on the frequency of dangerous posture changes is shown in Figure 2. Sows that had previously farrowed in the pens performed fewer rolling ($P < 0.05$) and sit-to-lie posture changes ($P < 0.05$), and therefore fewer total dangerous posture changes ($P < 0.05$), during farrowing than sows which previously farrowed in the

360s. Frequency of posture changes during the early farrowing interval increased with increasing early farrowing interval duration ($P < 0.01$). The total frequency of dangerous posture changes increased with increasing total farrowing duration (+0.041 ± 0.010 per min; $P < 0.001$), specifically the frequency of rolling (+0.018 ± 0.006 per min; $P = 0.01$) and sit-to-lie (+0.018 ± 0.005 per min; $P < 0.01$), but not stand-to-lie posture changes.

3.3. Post-partum nursing

The effect of pre-partum nesting behaviour on post-partum behaviour is shown in Table 4. The percentage of successful nursing bouts decreased as the percentage of pre-partum nesting observations increased ($P < 0.01$), and with earlier final nesting and standing bouts (both $P < 0.05$); whilst the average duration of successful nursing bouts increased with a lower peak nesting intensity ($P < 0.01$), an earlier peak hour of nesting ($P < 0.05$) and a later final posture change before BFP ($P < 0.05$).

3.3.1. Nursing behaviours

The effect of the previous farrowing system on post-partum nursing behaviours is shown in Table 5. Most notably, sows which previously farrowed in the 360s displayed an increased frequency of sow-terminated nursing ($P < 0.001$), decreased duration of successful nursing bouts ($P < 0.05$) and a longer interval between successful nursing bouts ($P < 0.05$) than sows which previously farrowed in the pens. The average duration of successful nursing bouts was significantly longer in the autumn/winter (10.21mins ± 0.37) than the spring/summer (8.92mins; $P < 0.05$). The percentage of nursing bouts which ended with more than five piglets asleep at the udder was also significantly higher in the autumn/winter season (53.1% ± 3.8) than the spring/summer (39.1% ± 4.0; $P < 0.05$). The percentage of nursing bouts with the udder facing the creep tended to be higher with the creep on the left than the right side of the pen (89.5% ± 5.5 vs. 75.8% ± 4.8; $P = 0.076$). The percentage of nursing bouts ending with more than five piglets asleep at the udder decreased with an increasing frequency of both successful nursing bouts ($P < 0.05$) and sow terminated nursing bouts ($P < 0.0001$).

3.3.2. Percentage of time in different postures

Sows that had previously farrowed in the pens spent significantly longer lying laterally (72.5% ± 2.3; $P < 0.05$), and tended to spend less time lying ventrally (12.5% ± 2.0; $P = 0.090$), than sows that had previously farrowed in the 360s (lateral= 64.0% ± 2.5; ventral= 17.7% ± 2.1). Sows that farrowed in the spring/summer spent less time lying ventrally (11.8% ± 2.1; $P < 0.05$) and more time outside (5.83% ± 0.64; $P < 0.001$) than sows that farrowed during the autumn/winter season (ventral= 18.4% ± 2.0; outside= 1.99% ± 0.61).

3.3.3. Frequency of dangerous posture changes

Frequency of rolling was lower for sows that previously farrowed in the pens (17.4 ± 2.6) than the 360s (26.3 ± 2.7; $P < 0.05$). No other effects of the previous farrowing system, current season or total born litter size were found.

4. Discussion

The current research confirms findings by earlier studies that the previous farrowing system affects current sow behaviour throughout farrowing (Thodberg *et al.*, 2002a, 2002b). However, this is the first study to find such a profound effect of the previous farrowing system on sow farrowing behaviour. These experiential effects on sow behaviour may have contributed to the differences in piglet mortality related to previous farrowing experience which were observed in a more extensive analysis of production results on the same farm (King et al., 2018). A strength of the current study is that sow behaviour is compared within the same farrowing system, and therefore the only difference between experimental treatments is the previous farrowing system of the animals. However, a limitation of this experimental design is that it cannot be elucidated whether the poorer maternal behaviour of previously confined sows was caused by the previous experience of farrowing in confinement or an inherent effect of changing the farrowing system between parities, regardless of the direction of change. Either way, the behavioural differences observed are suggestive of a detrimental response occurring within the previously confined sows.

Whilst there were no experiential effects on the total amount of nest-building behaviour, results showed a tendency for prior free farrowing experience to result in a higher nesting intensity peak. This might suggest that the nest-building behaviour of these sows was less fragmented, and therefore more proficient. The nest-building behaviour of previously penned sows may have been more developed during the second parity due to learning and subsequent improvement of these behaviours with prior experience; whereas previously confined sows may have adapted their nest-building behaviours to the constraints of their previous farrowing environment. Alternatively, as sow nesting behaviour is internally motivated by pre-partum hormonal changes (Algers and Uvnäs-Moberg, 2007), its progress may be disturbed by an animal's physiological responses to stress, similar to the effects of stress on the progress of parturition (Lawrence *et al.*, 1992). Although internally-motivated, nest-building is terminated by sufficient external feedback from the nest site to affirm that the nest has been completed (Jensen, 1993). Therefore, the less proficient nest-building of previously confined sows may have delayed the termination of nest-building, resulting in the observed tendency for a shorter latency between standing and the start of farrowing and later increased restlessness throughout farrowing, due to unsatisfactory environmental feedback from the nest to terminate the nest-building behaviour, often seen amongst confined sows (Damm et al., 2003; Jarvis et al., 2001).

Whilst previously confined sows displayed increased restlessness during parturition, there were no observable differences in the frequency or duration of standing behaviour, therefore the increased restlessness is unlikely to have resulted from a continued performance of nest-building behaviour after the commencement of farrowing. Increased sitting behaviour during parturition has been found previously within crated sows (Damm *et al.*, 2003; Jarvis *et al.*, 1997; Jarvis *et al.*, 2004), and may be indicative of a motivational conflict from the inability to nest-build in confinement (Jarvis *et al.*, 2004). Confined sows also exhibit increased restlessness and physiological stress responses in comparison to free farrowing sows (Jarvis *et al.*, 1997; Lawrence *et al.*, 1994). As previous studies have already shown farrowing behaviour to develop over successive parities (Jarvis *et al.* 2001; Thodberg *et al.* 2002a, 2002b), previously crated sows may have performed increased sitting and restlessness during parturition in response to confinement in their first parity, with these behaviours persisting during the observed subsequent parturition in a free farrowing pen. This may be similar to, but less severe than, animals continuing to perform stereotypical behaviours which developed in a poor environment when rehoused in an enriched environment (Mason, 1991). Conversely, Thodberg *et al.* (2002a) found increased restlessness during parturition in sows that were previously housed in a free farrowing system. However, in their study, all sows were housed in gestation stalls between the first and second farrowing, therefore sows may have become less reactive to confinement during the second parturition. The effect of the gestation environment has been highlighted in another study, whereby group-housed sows were more restless during parturition in farrowing crates than sows which had been stall housed throughout gestation (Boyle *et al.*, 2002).

The previous farrowing system also affected post-partum nursing behaviours, with a decreased duration of successful nursing bouts and increased incidence of sow-terminated nursing by sows which previously farrowed in the 360s. Sow-terminated nursing bouts are undesirable as they increase the frequency of sow rolling, therefore increasing the risk of piglet crushing, especially in free farrowing systems (Weary *et al.* 1996a). Sow-terminated nursing bouts also limit the opportunity for piglets to perform post-nursing udder massage as a means of increasing sow milk production (Jensen *et al.*, 1991). It is speculated that previously confined sows may continue to experience increased stress, causing stress-related hormones to interfere with oxytocin expression associated with parturition. Consequently, the oxytocin-induced reduced responsiveness of sows during parturition (Jarvis *et al.*, 1999), and the acceptance of, and bonding with, piglets post-partum may be disrupted by the hormonal modulation of stress (Jarvis *et al.*, 1997), resulting in the increased partum and post-partum restlessness and compromised nursing behaviour of previously confined sows.

Additionally, piglets were found to sleep at the udder more if a sow previously farrowed in the 360s, which may have been a consequence of the poorer nursing behaviour of these sows. A previous study by Weary *et al.* (1996b) found that both individual piglets and entire litters who spent more time active underneath the sow when she was standing or sitting had lower weight gain, whilst the majority of crushed piglets are identified as also being malnourished (Dyck and Swierstra, 1987). Therefore, excessive lying at the udder by piglets may be an indicator that those individual piglets, or the entire litter, are becoming undernourished and may require supplementary feeding to reduce the risk of piglet mortality by starvation or the subsequent increased risk of crushing.

Not only does the current study confirm the effect of prior experience, but the findings also suggest that sows adapt their behaviour depending on the time of year at parturition. One of the primary functions for performing pre-partum nest-building in the wild is to provide a shelter and microclimate for the neonates (Algers and Jensen, 1990), whilst a previous study on sows in a semi-natural environment found sows to adapt their choice of nest site and collection of nesting material across seasons (Jensen, 1989). However, to our knowledge, no previous studies have described seasonal variation in both pre-partum nest-building and post-partum nursing behaviours in a commercial setting. Successful nursing bouts may have been longer in the autumn/winter due to increased demand for milk by the litter, although whether this demand was fulfilled by the sow via increased milk supply cannot be determined. The percentage of nursing bouts ending with piglets asleep at the udder was also increased during the autumn/winter months, as well as with a decreasing frequency of successful nursing bouts, suggesting piglets risked resting at the udder when their nutritional requirements were not being met. However, lying at the udder may also increase during the colder months as the piglets are attracted to the additional warmth radiating from the udder (Weary *et al.* 1996b).

Furthermore, individual variation in pre-partum nesting behaviour had significant associations with parturient and post-partum behaviours of the sow. As pre-partum nesting behaviour was so strongly affected by the season of farrowing in the current study, these associations may be reflective of sow responsiveness to climatic temperature fluctuations. For example, sows with more observations of pre-partum nesting exhibited increased ventral and reduced lateral lying during parturition, with an increased ratio of ventral to lateral lying previously associated with colder room temperatures amongst gilts (Canaday et al., 2013).

Whilst an increased latency between the last nesting bout and BFP was associated with desirable behaviour during parturition (i.e. increased latency to first posture change), this measure was associated with undesirable post-partum behaviours (increased percentage of time outside of the nest and an increased successful nursing bout interval). Thodberg *et al.* (2002a) found an increased latency between the last nesting bout and BFP to be associated with an escape response during a pre-pubertal human test. Therefore, this nest-building behavioural measure may be associated with a flighty behavioural response to stress, including the post-partum avoidance of the litter indicated in the current study. An increased latency between the peak hour of nesting and BFP was associated with a decreased frequency of posture changes during the early farrowing interval in both Thodberg *et al.* (2002a) and the current study, which could be due to individual differences in the hormonal control of both pre-partum nesting and sow passivity during parturition (Algers and Uvnäs-Moberg, 2007).

In conclusion, sow farrowing behaviour was affected by the previous farrowing system, as confinement during the previous farrowing was associated with increased fragmentation of pre-partum nesting, increased restlessness during parturition and poorer post-partum nursing behaviour. These differences provide further evidence that farrowing behaviour develops with experience, as housing in a restrictive environment at farrowing had a detrimental effect on later farrowing behaviour in a free farrowing system. Domesticated sows also possessed the ability to adapt their nesting and nursing behaviour according to climatic variation.

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Tables

Table 1. Description of pre-partum behavioural measures adapted from Thodberg (2002a), and post-partum sow nursing behaviours.

Behavioural measure	Description
Pre-partum nesting	
Peak intensity	Frequency of nesting observations during peak hour of nesting (max. 12)
Peak nest	Latency between peak hour of nesting and BFP (hours)
Last nest	Latency between last two consecutive nesting bouts and BFP (hours)
Last posture	Latency between last posture change and BFP (mins)
Last stand	Latency between last standing observation and BFP (mins)
Turning	Sow is turning around by 180º or more whilst standing
Post-partum nursing	
Nursing bout	Starts/ends when over/under 50% of the litter are active at the udder, respectively
Successful nursing bout	Piglets perform rapid sucking behaviour for > 20 seconds (Whittemore & Fraser, 1974)
Sow terminated nursing bout	Sow ends nursing bout by changing posture (includes both successful and unsuccessful nursings)
Udder facing creep	Sow lying laterally with back towards farrowing rail and udder facing towards the piglet creep area
Piglets asleep at udder	>5 piglets asleep within one piglet’s length of the sow’s udder after nursing (includes both successful and unsuccessful nursings)

Table 2. Least square means, standard error and *P* value for nest-building behaviours during the 24h before the birth of the first piglet which were significantly affected by season.

Nesting behaviour	Spring/Summer (Apr-Sep)	Autumn/Winter (Oct-Mar)	s.e.	*P*
Standing (%)	17.4	27.2	2.01	0.01
Nesting (%)	12.0	17.5	1.12	0.01
Turning (%)	0.17	1.07	0.16	0.001
None (%)	87.1	80.3	1.25	0.001
Peak intensity*	6.39	8.43	0.52	0.05

*Frequency of nesting behaviour during peak hour of nesting, scale of 0-12 observations

Table 3. Associations between pre-partum nesting and partum behaviours (see Table 1 for definitions of pre-partum behavioural measures).

	Pre-partum behavioural measure					
		Peak	Peak	Last	Last	Last
Percentages of postures						
Standing						
Sitting			**(-)			
Ventral	***				***	
Lateral	***(-)				*(-)	
Early posture changes						
First posture				***		
Early interval	*		**(-)		*	
Dangerous posture						
Rolling						
Stand-to-lie				*(-)		
Sit-to-lie						
Total	*					

** P < 0.05 ** P < 0.01 *** P < 0.001*

(-) denotes a negative association

Table 4. Associations between pre-partum nesting and post-partum sow behaviour (see Table 1 for definitions of pre-partum behavioural measures).

	Pre-partum behavioural measure					
Post-partum behaviour	Nest	Peak intensit	Peak nest	Last nest	Last stand	Last postur
Nursing behaviour						
Successful frequency	*(-)			**(-)	*(-)	
Terminated frequency	*					
All nursing frequency						
Successful avg. duration		**(-)	*			*(-)
Terminated avg. duration						
All nursing avg. duration		*(-)	*			*(-)
Successful nursing interval	*			***	*	
%age successful	*(-)			**(-)	*(-)	
%age terminated						
%age towards creep					***(-)	
%age asleep at udder						
Percentages of postures						
Standing						
Sitting	*(-)	*				
Ventral						
Lateral						
Outside				***		
Dangerous posture changes						
Rolling	**					
Stand-to-lie						
Sit-to-lie						
Total						

** P < 0.05 ** P < 0.01 *** P < 0.001*

(-) denotes a negative association

Table 5. Least square means (± s.e.) and *P* value (ns(*P* > 0.10)) for the effect of the previous farrowing system on post-partum nursing behaviour.

Sow nursing behaviour	Pens	360s	*P*
Nursing frequency			
Successful	21.68 ±	18.95 ± 0.98	0.10
Sow-terminated	7.20 ± 0.58	10.98 ± 0.62	0.001
All nursing bouts	33.45 ±	33.90 ± 1.26	ns
Average nursing bout duration			
Successful	10.42 ±	8.72 ± 0.40	0.05
Sow-terminated	6.24 ± 0.55	6.23 ± 0.58	ns
All nursing bouts	9.51 ± 0.38	7.80 ± 0.40	0.05
Percentage of all nursing bouts			
Successful	67.29 ±	55.58 ± 3.85	0.10
Sow-terminated	24.02 ±	30.58 ± 1.32	0.01
Udder facing creep	79.04 ±	84.66 ± 5.27	ns
Asleep at the udder	39.22 ±	53.32 ± 3.94	0.10
Successful nursing interval (mins)	65.97 ±	83.10 ± 4.97	0.05

Figures

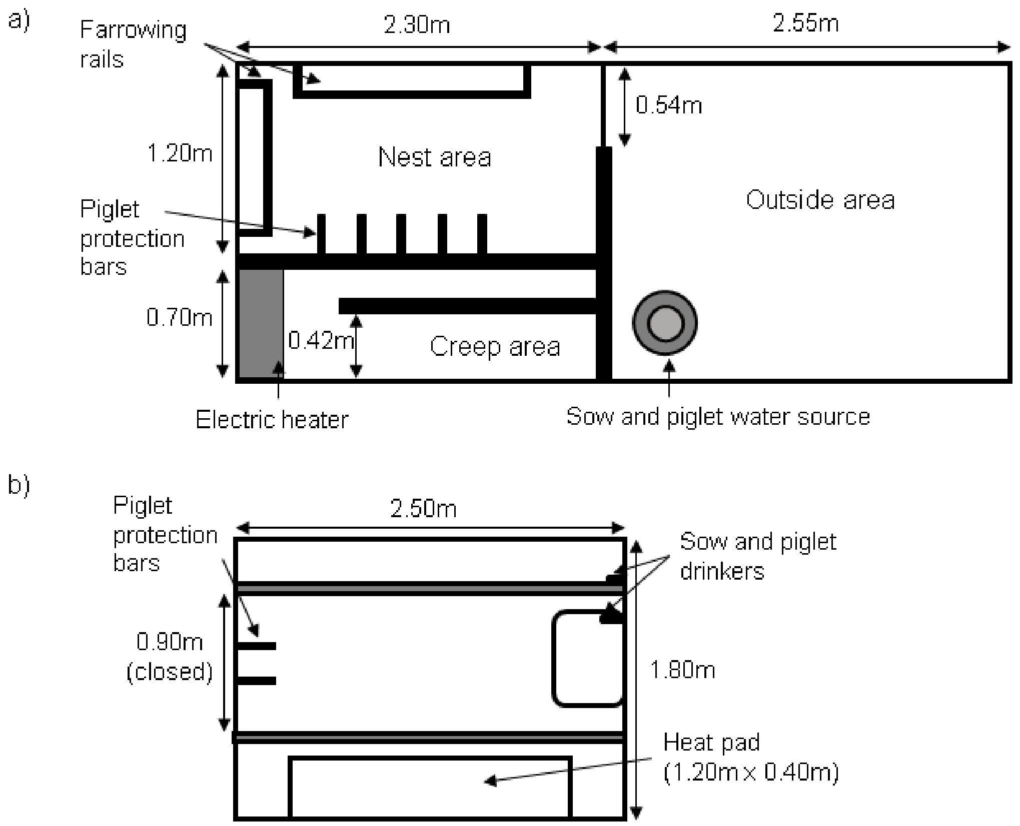

Figure 1. Sow farrowing pen layouts illustrating dimensions for (a) the straw-based pen with outside run and (b) the 360º Freedom Farrower.

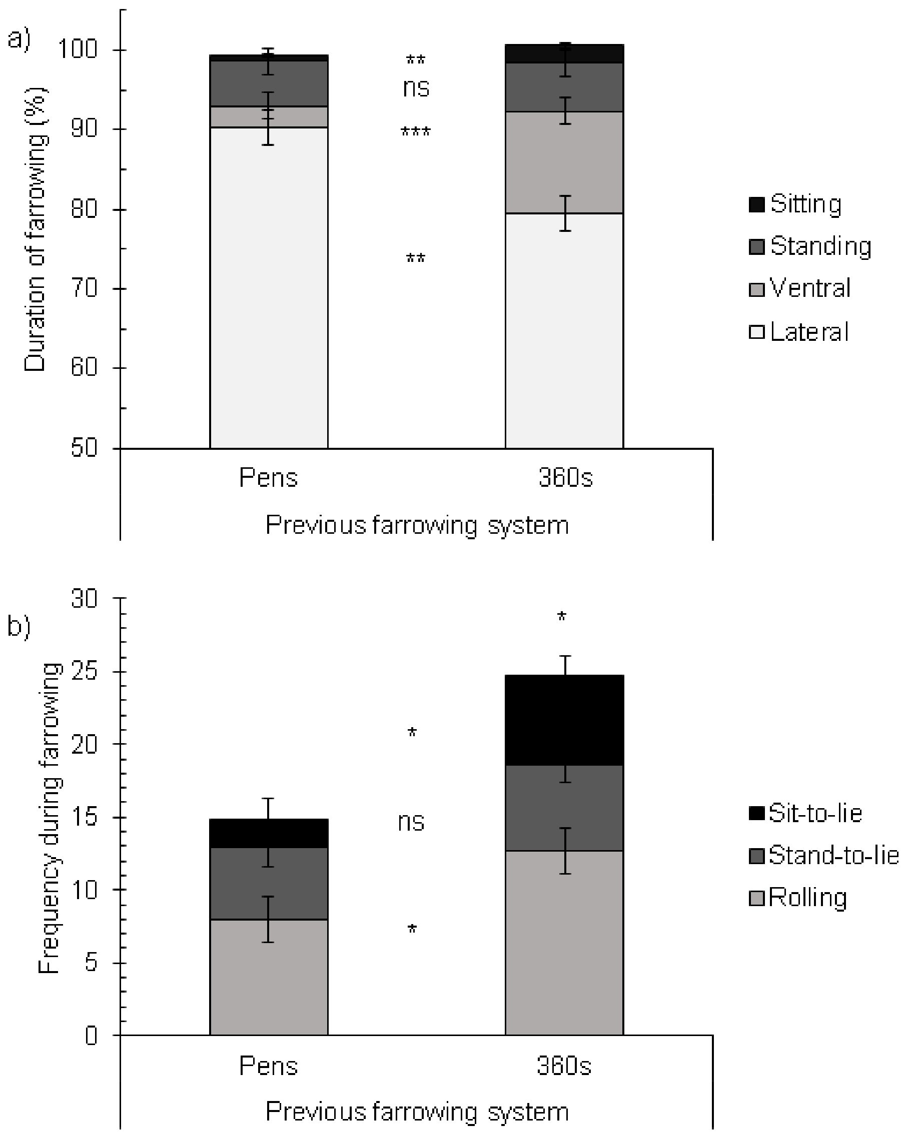

Figure 2. Least square means (± s.e.) for previous farrowing system effects on partum (a) sow posture durations (%) and (b) sow dangerous posture change frequencies. The effect of the previous farrowing system is indicated for each posture (a and b; between systems) and total posture changes (b only; above latter system; ns($P > 0.05$), *($P < 0.05$), **($P < 0.01$), ***($P < 0.001$)).