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Author	Ahsan Mehtab ^{1,2,†} , Hong-Seok Mun ^{1,3,†} , Eddiemar B. Lagua ^{1,4} , Md Sharifuzzaman ^{1,5} , Md Kamrul Hasan ^{1,6} , Young-Hwa Kim ⁷ , Kang Jin Gu ^{1,4} and Chul-Ju Yang ^{1,4,*}
Affiliation	<p>¹ Animal Nutrition and Feed Science Laboratory, Department of Animal Science and Technology, Sunchon National University, Suncheon 57922, Republic of Korea; ahsanmehtab50@gmail.com, mhs88828@nate.com, eddiemarlagua@gmail.com, baushossain@gmail.com, kamrul.ps@sau.ac.bd, yhkim8760@naver.com, yangcj@scnu.ac.kr,</p> <p>² School Education Department (Narowal), Punjab, Pakistan; ahsanmehtab50@gmail.com</p> <p>³ Department of Multimedia Engineering, Sunchon National University, Suncheon 57922, Republic of Korea; mhs88828@nate.com</p> <p>⁴ Interdisciplinary Program in IT-Bio Convergence System (BK21 Plus), Sunchon National University, Suncheon 57922, Republic of Korea; eddiemarlagua@gmail.com, yangcj@scnu.ac.kr</p> <p>⁵ Department of Animal Science and Veterinary Medicine, Gopalganj Science and Technology University, Gopalganj 8100, Bangladesh; baushossain@gmail.com</p> <p>⁶ Department of Poultry Science, Sylhet Agricultural University, Sylhet 3100, Bangladesh; kamrul.ps@sau.ac.bd</p> <p>⁷ Interdisciplinary Program in IT-Bio Convergence System (BK21 Plus), Chonnam National</p>

	<p>University, Gwangju 61186, Republic of Korea; yhkim8760@naver.com</p> <p>† These authors contributed equally to this work.</p> <p>* Correspondence: yangcj@scnu.ac.kr; Tel.: +82-61-750-3235</p>
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5 **CORRESPONDING AUTHOR CONTACT INFORMATION**

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9 **Article Title: Precision livestock monitoring of lactating**
10 **sows: YOLOv8-based behavioral analysis under varying**
11 **feeding strategies**

12 **Running Title: YOLOv8 for sow monitoring**

13 Ahsan Mehtab^{1,2,†}, Hong-Seok Mun^{1,3,†}, Eddiemar B. Laguna^{1,4}, Md Sharifuzzaman^{1,5}, Md Kamrul Hasan^{1,6},
14 Young-Hwa Kim⁷, Kang Jin Gu^{1,4} and Chul-Ju Yang^{1,4,*}

15 ¹ Animal Nutrition and Feed Science Laboratory, Department of Animal Science and Technology, Suncheon
16 National University, Suncheon 57922, Republic of Korea; ahsanmehtab50@gmail.com, mhs88828@nate.com,
17 eddiemarlagua@gmail.com, baushossain@gmail.com, kamrul.ps@sau.ac.bd, kookoo5018@naver.com,
18 yhkim8760@naver.com, yangcj@scnu.ac.kr,

19 ² School Education Department (Narowal), Punjab, Pakistan; ahsanmehtab50@gmail.com

20 ³ Department of Multimedia Engineering, Suncheon National University, Suncheon 57922, Republic of Korea;
21 mhs88828@nate.com

22 ⁴ Interdisciplinary Program in IT-Bio Convergence System (BK21 Plus), Suncheon National University, Suncheon
23 57922, Republic of Korea; eddiemarlagua@gmail.com, kookoo5018@naver.com, yangcj@scnu.ac.kr

24 ⁵ Department of Animal Science and Veterinary Medicine, Gopalganj Science and Technology University,
25 Gopalganj 8100, Bangladesh; baushossain@gmail.com

26 ⁶ Department of Poultry Science, Sylhet Agricultural University, Sylhet 3100, Bangladesh; kamrul.ps@sau.ac.bd

27 ⁷ Interdisciplinary Program in IT-Bio Convergence System (BK21 Plus), Chonnam National University, Gwangju
28 61186, Republic of Korea; yhkim8760@naver.com

29 † These authors contributed equally to this work.

30 * Correspondence: yangcj@scnu.ac.kr; Tel.: +82-61-750-3235

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33
34

35 **Abstract**

36 Feeding frequency and thermal environment are key factors influencing the behavior and welfare of lactating
37 sows, as well as piglet access to milk. This study employed a deep learning-based computer vision approach using
38 the YOLOv8l (You Only Look Once version 8 – large) model to automate multi-class behavior detection in
39 lactating sows. Eight distinct behaviors were classified: feeding, not feeding, suckling, not suckling, lateral lying,
40 sternal lying, standing, and sitting. The model achieved high performance (precision = 0.943, recall = 0.950, F1-
41 score = 0.946, mAP@50 = 0.965). Three treatment groups were evaluated: Group 1 (feeding five times/day, air-
42 conditioned), Group 2 (hourly feeding, air-conditioned), and Group 3 (hourly feeding, non-air-conditioned).
43 Group 2 exhibited the highest suckling frequency (38.75; $p = 0.035$), feeding frequency (32.97; $p < 0.001$), and
44 the shortest feeding interval (30.21 min; $p < 0.001$), suggesting enhanced interaction under frequent feeding with
45 thermal control. Group 3 showed significantly higher lateral lying frequency (27.26; $p < 0.001$), consistent with
46 thermoregulatory behavior in warmer environments. Postural dynamics also varied: sternal lying was highest in
47 group 2 (45.56; $p < 0.001$), while standing was more frequent in Group 2 (29.25; $p < 0.001$) but of shorter duration.
48 These findings demonstrate that hourly feeding under air-conditioned conditions promotes more frequent feeding
49 and suckling behaviors, while heat stress influences lying patterns. The YOLOv8l model proved to be a robust
50 tool for automated behavior detection, supporting its applicability in precision livestock monitoring systems.

51 **Keywords:** feeding frequency; thermal environment; computer vision; YOLOv8; behavioral monitoring; posture
52 analysis.

53 **Introduction**

54 Lactation is a critical period for both sow welfare and piglet performance. During this time, maternal
55 behavior, including feeding, nursing frequency, and postural choices, directly affects milk synthesis, piglet access,
56 and sow energy balance, which in turn influence piglet growth and survival [1–4]. Two management factors that
57 strongly modulate lactating sow behavior are feeding regime and ambient thermal environment. Feeding
58 frequency alters the temporal distribution of feed intake and associated activity (feeding, standing, and feeding-
59 related restlessness), while thermal stress drives behavioral thermoregulation, most notably increased lateral

60 recumbency and reduced standing [5–10]. Understanding how these factors interact is essential for designing
61 feeding and housing strategies that optimize both sow welfare and production [11,12].

62 Traditional behavior observation methods rely on human scoring or intermittent sampling, which are
63 labor-intensive and prone to observer bias. Recent advances in computer vision offer scalable and objective
64 approaches for continuous behavior monitoring in livestock production systems [13–16]. In particular, one-stage
65 object detectors of the YOLO (You Only Look Once) family have become widely adopted in agricultural contexts
66 because they provide a balance between detection accuracy and inference speed, which is essential for near real-
67 time applications [17–21]. YOLOv8, the latest Ultralytics implementation, introduces several architectural
68 refinements, including an anchor-free detection head, improved backbone and neck designs, and modern training
69 optimizers. These improvements enhance detection performance while maintaining operational efficiency,
70 making YOLOv8 suitable for multi-class behavior recognition in complex barn environments [17,19,22].

71 Despite growing interest in automated behavior detection, relatively few studies have combined high-
72 resolution, frame-based detection with experimental manipulation of both feeding schedule and thermal
73 conditions. Most previous investigations have examined feeding frequency or heat stress in isolation and have
74 relied on manual observations or coarse behavioral indicators [5–8,23]. As a result, the interactive effects of
75 feeding frequency and thermal environment on fine-scale sow behavioral dynamics remain insufficiently
76 quantified. Therefore, the objective of this study was to quantify lactating sow behavioral dynamics using a
77 YOLOv8-based computer vision framework under different feeding frequencies and thermal environments. We
78 hypothesized that both feeding frequency and thermal stress would influence the temporal distribution of maternal
79 behaviors and that automated high-resolution detection would reveal interaction effects between nutritional and
80 environmental factors.

81 **Materials and Methods**

82 **Ethical Approval**

83 All experimental procedures involving animals were reviewed and approved by the Institutional Animal
84 Care and Use Committee (IACUC) of Sunchon National University, Republic of Korea (Approval No. SCNU
85 IACUC-2023-21). The study was conducted in accordance with institutional and national guidelines for the care

86 and use of experimental animals. Animal handling and management procedures followed institutional animal care
87 guidelines throughout the experimental period.

88 **Experimental design**

89 The experiment was conducted to evaluate the effects of feeding frequency and thermal environment
90 on lactating sow behavior. Fifteen lactating sows were randomly assigned to three treatment groups (n = 5 sows
91 per group). The treatments were conducted sequentially in the order Group 1, Group 2, and Group 3. Housing
92 conditions, management practices, and husbandry procedures were kept consistent across all experimental periods
93 except for feeding frequency and thermal environment. Identical housing facilities, management protocols, and
94 personnel were used for all treatment periods.

95 Group 1 sows were fed five times per day under air-conditioned housing conditions. Group 2 sows were
96 fed at hourly intervals under air-conditioned housing conditions. Group 3 sows were fed at hourly intervals under
97 non-air-conditioned housing conditions. Figure 1 illustrates the experimental workflow and behavioral detection
98 procedures. Ambient temperature, relative humidity, THI, and behavioral variables (feeding, posture, and suckling)
99 were recorded throughout the experimental period. Physiological stress indicators such as rectal temperature and
100 respiratory rate were not measured in this study; stress evaluation was based on environmental indices (ambient
101 temperature and THI) and behavioral parameters.

102 **Animals and housing**

103 Fifteen multiparous Landrace × Yorkshire sows were maintained at the experimental pig farm of
104 Sunchon National University between June and September 2023. Parity ranged from 2 to 5, with mean ± SD parity
105 values of 3.4 ± 1.1 , 3.6 ± 0.9 , and 3.5 ± 1.0 for Groups 1, 2, and 3, respectively. During gestation, sows were
106 housed individually in gestation crates measuring 2.02×0.70 m and equipped with automatic feeding systems
107 and individual drinkers. All sows had ad libitum access to water. On day 107 of gestation, sows were weighed and
108 transferred to individual farrowing pens according to their assigned experimental group. Each farrowing pen
109 measured 2.60×2.90 m and contained a farrowing crate measuring 2.02×0.70 m with hinged bottom bars. A
110 brooder and a 250 W infrared heat lamp were installed to provide supplemental heat for piglets. Cross-fostering
111 was not performed. Litter size was recorded at farrowing and remained unchanged until weaning. Mean litter sizes

112 were 11.79 piglets per sow in Group 1, 12.79 in Group 2, and 11.93 in Group 3.

113 Groups 1 and 2 were housed in a climate-controlled farrowing facility equipped with an air-conditioning
114 system. Ambient temperature was maintained at 24.87 ± 1.12 °C and relative humidity at $61.0 \pm 4.3\%$, resulting
115 in a mean THI of approximately 71. Group 3 was housed in a non-air-conditioned farrowing facility measuring
116 8.0×10.0 m. In this environment, ambient temperature ranged from 28.1 to 32.7 °C and relative humidity
117 averaged $68.7 \pm 5.1\%$, resulting in a THI range of 76 to 82. Ambient temperature and relative humidity were
118 continuously monitored throughout the experimental period. THI was calculated using the equation proposed by
119 Buffington et al [24]:

$$120 \quad \text{THI} = (1.8 \times T + 32) - (0.55 - 0.0055 \times \text{RH}) \times (1.8 \times T - 26) \quad (1)$$

121 where T represents ambient temperature (°C) and RH represents relative humidity (%).

122 **Feeding treatments**

123 During gestation, all sows received a corn soybean meal-based diet containing 16% crude protein, 3,200
124 kcal/kg digestible energy, and 0.50% standardized ileal digestible lysine (SID Lys) [18,19]. During lactation, the
125 diet contained 3,400 kcal/kg digestible energy, 18% crude protein, 0.80% SID Lys, 5.50% crude fat, 10% crude
126 ash, 9% crude fiber, 0.55% calcium, and 1.50% phosphorus. During gestation, all sows received 2.50 kg feed per
127 day.

128 From farrowing until three days postpartum, sows in Group 1 were fed manually five times per day at
129 08:00, 11:00, 14:00, 17:00, and 22:00. The total daily feed allowance was evenly divided into five portions. Feed
130 allowance increased progressively during lactation, starting at 2.90 kg on day 1 postpartum, increasing to 3.70 kg
131 during days 2 to 6, 6.00 kg during days 7 to 13, 8.50 kg during days 14 to 15, and 9.00 kg during days 16 to 28.
132 Average daily feed intake was 6.77 ± 0.42 , 9.34 ± 0.51 , and 7.51 ± 0.47 kg/day for Groups 1, 2, and 3, respectively,
133 based on daily intake records collected for each sow throughout the experimental period. Feed intake values
134 represent actual recorded consumption per sow and not theoretical feed allowance. Feeding was controlled and
135 not provided ad libitum.

136 From day 4 postpartum until weaning on day 21, sows in Groups 2 and 3 were fed at hourly intervals
137 using an automatic feeding system (Iontec, Incheon, South Korea). The system dispensed feed in 200 g portions
138 per activation, with a maximum delivery rate of 800 g per hour per sow. The hourly feeding rate was set based on
139 a preliminary one-month assessment conducted in five sows; data from this assessment were not included in the
140 statistical analysis.

141 **Video Surveillance and Behavioral Data Collection**

142 Sow behavior was continuously recorded from farrowing until day 21 of lactation using a network
143 camera (PNO-A6081R, Hanwha Vision Co., Ltd., South Korea) with a resolution of 2560×1920 pixels and a
144 frame rate of 30 frames per second. Each sow was monitored continuously for 24 hours per day. Video recordings
145 were used to quantify feeding, suckling, standing, sitting, lateral lying, and sternal lying behaviors. Images were
146 extracted from video recordings at five-second intervals using Python and the OpenCV library and stored at a
147 resolution of 1920×1080 pixels. A total of 9,487 images were manually annotated using Roboflow. Eight
148 behavioral classes were defined: feeding, not feeding, suckling, not suckling, lateral lying, sternal lying, standing,
149 and sitting. The number of annotations and definitions for each class are provided in Tables 1 and 2, respectively.

150 After augmentation, the dataset consisted of 22,583 images, divided into training (19,644 images, 87%),
151 validation (1,903 images, 8%), and test (1,036 images, 5%) sets (Fig. 2). Preprocessing included auto-orientation
152 of images. Data augmentation consisted of horizontal flipping, brightness adjustment between -25% and $+25\%$,
153 blurring up to 1.5 pixels, and noise addition of up to 0.6% of pixels. YOLOv8n, YOLOv8s, YOLOv8m, and
154 YOLOv8l models were trained and evaluated using the Ultralytics YOLOv8 framework version 8.3.56. Training
155 was conducted using Python 3.11.6 with PyTorch 2.5.1 and CUDA 12.4 on an NVIDIA GeForce RTX 4090 GPU.
156 Mixed-precision training and adaptive learning rate scheduling were applied. The YOLOv8l model was used for
157 behavioral analysis.

158 **Statistical analysis**

159 Behavioral parameters, including the frequency and duration of feeding, not feeding, suckling, not
160 suckling, lateral lying, sternal lying, standing, and sitting, were calculated for each sow. Daily behavioral measures
161 were averaged per sow over the 21-day lactation period prior to statistical analysis. One-way analysis of variance

162 was conducted using Python with the `scipy.stats` and `statsmodels` libraries. Tukey's post-hoc test was applied for
163 pairwise comparisons. Statistical significance was defined as $p < 0.05$.

164 **Results**

165 **Comparison of YOLOv8 model variants**

166 Using an input size of 640×640 pixels, all YOLOv8 variants achieved high detection accuracy (Table
167 3). Validation F1-scores and mAP@0.5 to 0.95 increased with model size. YOLOv8l achieved a validation F1-
168 score of 0.957 and mAP@0.5 to 0.95 of 0.878, while YOLOv8n, YOLOv8s, and YOLOv8m showed lower
169 performance values with reduced computational requirements.

170 **Overall model performance**

171 The YOLOv8l-based behavioral detection framework produced overall performance metrics of
172 precision = 0.943, recall = 0.950, and F1-score = 0.946 (Table 4). Localization metrics were mAP@0.5 = 0.965
173 and mAP@0.5 to 0.95 = 0.863. Class-level F1-scores were 0.993 for not feeding, 0.982 for standing, 0.981 for
174 lateral lying, 0.905 for sitting, 0.905 for suckling, and 0.906 for not suckling. Figure 3 presents a radar chart of
175 precision, recall, and F1-score across all behavioral classes.

176 **Confusion matrix and evaluation metrics**

177 The confusion matrix (Fig. 4) shows the distribution of classified behaviors. Correct classification
178 counts were 1521 for not feeding and 1145 for not suckling. Misclassifications were observed between sternal
179 lying and standing and between suckling and not suckling. Precision, recall, and F1-score were calculated as
180 follows:

$$181 \text{ Precision} = \frac{\text{true positive}}{\text{true positive} + \text{false positive}} \quad (1)$$

$$182 \text{ Recall} = \frac{\text{true positive}}{\text{true positive} + \text{false negative}} \quad (2)$$

183
$$F1 - \text{score} = 2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}} \quad (3)$$

184 True positives correspond to the diagonal elements of the confusion matrix. False positives were
185 calculated as the row sum minus true positives, false negatives as the column sum minus true positives, and true
186 negatives as all remaining correctly classified instances.

187 **Visual validation of behavior detection**

188 Detected behavioral categories under different postural and activity conditions are shown in Figure 5.
189 Lateral lying with suckling (Fig. 5A) and without suckling (Fig. 5B) had confidence scores above 0.90. Standing
190 associated with feeding (Fig. 5C), sternal lying without feeding or suckling (Fig. 5D), and sitting combined with
191 suckling and not feeding (Fig. 5E) were recorded. Instances of classification differences between suckling and not
192 suckling during sternal lying are shown in Figure 5F.

193 **Behavioral differences across experimental groups**

194 Behavioral parameters differed among the three experimental groups (Table 5; Figs. 6 to 8).

195 **Feeding and suckling behavior**

196 Feeding frequency was 14.83 ± 1.46 , 32.97 ± 1.46 , and 20.00 ± 1.46 times per day, and feeding intervals
197 were 58.47 ± 3.46 , 30.21 ± 3.46 , and 49.30 ± 3.46 minutes for Groups 1, 2, and 3, respectively ($p < 0.001$).
198 Suckling duration ranged from 9.76 to 11.02 minutes across all groups and did not differ significantly, whereas
199 suckling frequency differed among treatments (34.14 ± 1.62 , 38.75 ± 1.62 , and 37.17 ± 1.62 times per day for
200 Groups 1, 2, and 3, respectively; $p = 0.035$) (Table 5; Figs. 6, 8).

201 **Postural behavior**

202 Lateral lying frequency was 17.00 ± 1.50 , 21.65 ± 1.50 , and 27.26 ± 1.50 for Groups 1, 2, and 3,
203 respectively ($p < 0.001$), while sternal lying frequency was 34.02 ± 1.78 , 45.56 ± 1.78 , and 29.14 ± 1.78 for
204 Groups 1, 2, and 3, respectively ($p < 0.001$). Standing duration was 12.10 ± 0.61 , 5.85 ± 0.61 , and 9.59 ± 0.61
205 minutes for Groups 1, 2, and 3, respectively ($p < 0.001$). Sitting frequency was 26.43 ± 1.70 , 15.38 ± 1.70 , and

206 20.93 ± 1.70 times per day for Groups 1, 2, and 3, respectively ($p < 0.001$), while sitting duration did not differ
207 significantly among groups ($p = 0.462$) (Table 5; Figs. 7, 8).

208 Figure 6 presents daily trends in feeding and suckling behaviors. Figure 7 presents summaries of
209 postural behavior frequencies and durations, and Figure 8 presents a heatmap of group-level differences in feeding,
210 suckling, and postural behaviors.

211 Discussion

212 The detection performance of the YOLOv8l-based behavioral recognition system across eight sow
213 behaviors is presented in Tables 3 and 4 and Figures 3–5. Higher accuracy was achieved for visually distinct and
214 static behaviors such as not feeding and standing, whereas lower performance was observed for transitional
215 behaviors such as sitting and not suckling. These differences are likely due to similarities in body posture. Limited
216 visual cues during short-duration or ambiguous activities may also reduce detection accuracy. Comparable
217 difficulties in recognizing transitional or overlapping postures have been reported in previous livestock behavior
218 studies using deep learning approaches [25,26]. The variation among behavior classes indicates that posture clarity
219 strongly influences detection performance in vision-based monitoring systems.

220 Comparison among YOLOv8 model variants further demonstrated that YOLOv8l achieved a balance
221 between detection accuracy and computational efficiency under farm conditions. Smaller models such as
222 YOLOv8n and YOLOv8s showed reduced detection performance, whereas larger models required increased
223 computational resources. The consistent detection of feeding, suckling, and postural behaviors by YOLOv8l
224 across different environmental and management conditions indicates its suitability for behavioral analysis in sow
225 housing systems [25,26].

226 Behavioral comparisons among treatment groups are summarized in Table 5 and Figures 6–8. Suckling
227 frequency was highest in Group 2, which received hourly feeding under air-conditioned conditions, while suckling
228 duration showed limited variation among groups. Feeding patterns differed according to treatment, with Group 2
229 exhibiting more frequent feeding events and shorter feeding intervals compared with Groups 1 and 3. These
230 findings indicate that feeding frequency influences the temporal distribution of sow activity and nursing behavior.

231 Similar responses to increased feeding frequency have been described in previous studies of sow feeding behavior
232 and activity patterns [25,27].

233 Postural behaviors also varied with environmental conditions. Group 3, housed in a non-air-conditioned
234 environment, exhibited a higher frequency of lateral lying than Groups 1 and 2. This posture has been associated
235 with thermoregulatory responses under elevated ambient temperatures and is commonly observed in heat-stressed
236 sows [1,7]. In contrast, Group 2 showed a higher frequency of sternal lying, which may reflect greater engagement
237 in feeding and nursing activities under controlled thermal conditions. Standing duration was lower in Group 2
238 than in the other groups, indicating differences in activity patterns associated with feeding management and
239 thermal environment. These results show that both feeding strategy and environmental conditions influence
240 postural and activity behaviors in lactating sows, consistent with previous reports on environmental effects on
241 sow behavior [5].

242 Overall, these findings demonstrate that precision feeding strategies combined with environmental
243 management can meaningfully influence sow welfare and activity patterns, highlighting the value of automated
244 behavior monitoring in production systems.

245 **Conclusion**

246 This study demonstrates that sow behavior is jointly influenced by feeding frequency and thermal environment
247 and can be reliably quantified using YOLOv8l-based automated detection. Hourly feeding in air-conditioned
248 housing increased feeding and suckling frequencies, reduced feeding intervals, and altered postural dynamics in
249 ways consistent with improved sow-piglet interaction. In contrast, hourly feeding under non-air-conditioned
250 conditions increased lateral lying, reflecting behavioral adaptation to heat stress. The YOLOv8l model achieved
251 high precision across eight behavior classes, confirming its value as a non-invasive tool for continuous monitoring
252 in production settings. These findings highlight the potential of integrating precision feeding strategies with
253 climate control to enhance sow welfare and productivity. Future studies will expand upon this design by including
254 a five-times-per-day feeding group under non-air-conditioned conditions, and by linking sow behavioral data with
255 piglet performance metrics to better inform data-driven management decisions.

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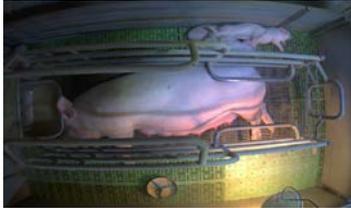
340 **Tables:**

341 **Table 1. Distribution of behavioral annotations across classes**

Behavioral Class	Annotation Count	Percentage (%)
Feeding	1,785	6.3
Not feeding	7,697	27.0
Suckling	3,346	11.7
Not suckling	6,184	21.7
Lateral lying	3,972	13.9
Sternal lying	2,291	8.0
Standing	2,191	7.7
Sitting	1,030	3.6
Total	28,496	100.0

342 **Table 2. Criteria for classification of behavior in lactating sows**

Behavior classes	Definitions	Sow postures
Feeding	Sow positioning her head within the feeder and actively engaging in feed intake	
Not feeding	Periods when the sow's head was not positioned inside the feeder and no feed intake activity was observed	
Suckling	Piglets were positioned at the sow's udder with direct teat attachment, actively engaging in milk consumption	
Not suckling	Periods when piglets were not attached to the sow's teats and no nursing activity was observed	

Lateral lying	When a sow rests on her side with legs extended, allowing piglets to access her teats for nursing	
Sternal lying	Sow resting on her belly with her legs tucked underneath or to the sides, limiting piglet access to her teats	
Standing	Sow maintaining an upright posture on all four legs, often associated with alertness, feeding, or movement.	
Sitting	Sow resting on her hindquarters with her forelimbs extended, resembling a dog-like posture and often seen during transitions between lying and standing	

343 **Table 3. Performance comparison of YOLOv8 model variants on behavioral detection**

Model version	Dataset	Precision	Recall	F1-score	mAP50	mAP50-95
YOLOv8n	train	0.988	0.987	0.988	0.993	0.916
	validation	0.951	0.961	0.956	0.978	0.869
	test	0.929	0.956	0.942	0.973	0.856
YOLOv8s	train	0.983	0.989	0.986	0.992	0.927

	validation	0.958	0.957	0.958	0.978	0.872
	test	0.945	0.948	0.947	0.974	0.861
YOLOv8m	train	0.995	0.994	0.995	0.994	0.948
	validation	0.956	0.956	0.956	0.978	0.878
	test	0.939	0.949	0.944	0.974	0.866
YOLOv8l	train	0.997	0.997	0.997	0.995	0.959
	validation	0.956	0.957	0.957	0.975	0.878
	test	0.943	0.950	0.946	0.964	0.863

344 **Table 4. Detection accuracy of the model**

Classes	Precision	Recall	F1-score	mAP@50	mAP@50-95
feeding	0.957	0.986	0.971	0.989	0.873
not feeding	0.995	0.991	0.993	0.995	0.947
suckling	0.909	0.902	0.905	0.95	0.772
not suckling	0.915	0.897	0.906	0.954	0.742
sitting	0.846	0.972	0.905	0.907	0.824
standing	0.991	0.973	0.982	0.992	0.933
sternal lying	0.942	0.904	0.923	0.938	0.886
lateral lying	0.986	0.976	0.981	0.991	0.928
average	0.943	0.950	0.946	0.965	0.863

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346 **Table 5. Average duration, interval, and frequency of sow behaviors during lactation in different groups.**

Parameters	Hourly feeding			SEM	p-value
	Group 1	Group 2	Group 3		
	(Air-conditioned)	(Air-conditioned)	(Non-air-conditioned)		
suckling duration (m)	10.88	11.02	9.76	0.583	0.318
suckling interval (m)	26.11	24.41	26.48	1.510	0.344
suckling frequency	34.14 ^b	38.75 ^a	37.17 ^{ab}	1.622	0.035

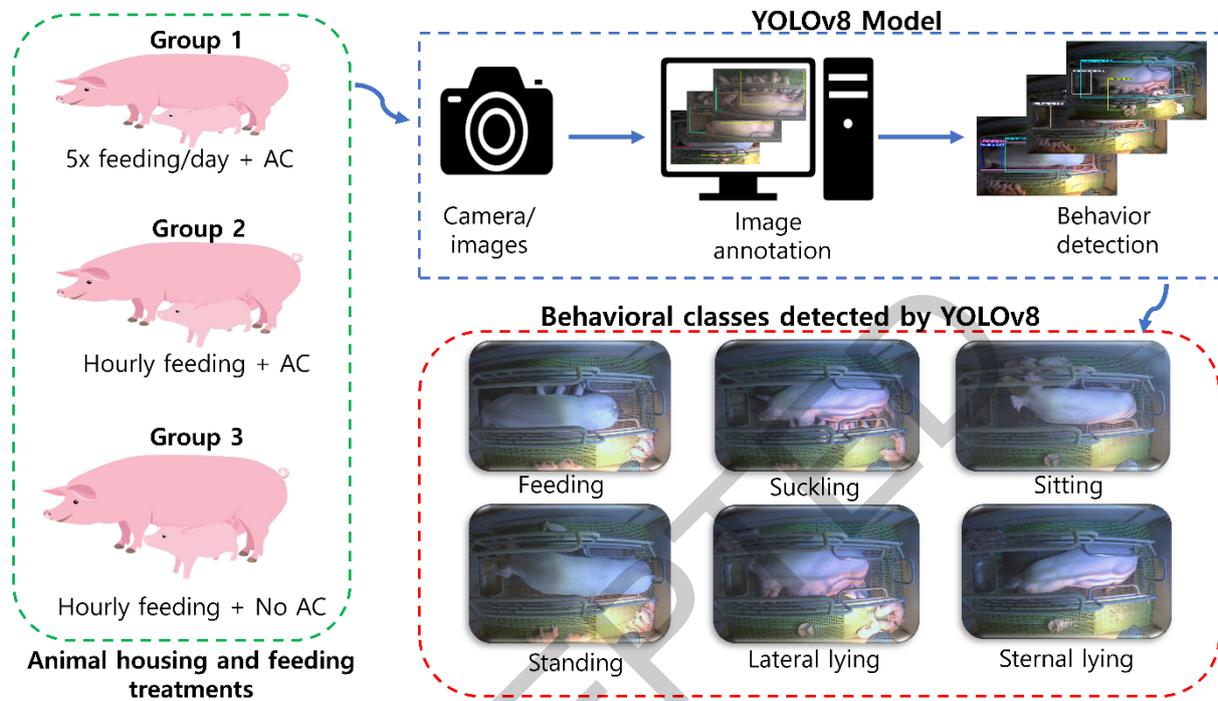
feeding/drinking duration (m)	6.29 ^a	4.76 ^b	6.54 ^a	0.373	<0.001
feeding/drinking interval (m)	58.47 ^a	30.21 ^c	49.30 ^b	3.457	<0.001
feeding/drinking frequency	14.83 ^c	32.97 ^a	20.00 ^b	1.462	<0.001
lateral lying duration (m)	41.26	36.97	28.27	2.590	0.079
lateral lying frequency	17.00 ^c	21.65 ^b	27.26 ^a	1.501	<0.001
sternal lying duration (m)	9.21 ^a	7.39 ^c	8.23 ^b	0.530	0.042
sternal lying frequency	34.02 ^b	45.56 ^a	29.14 ^c	1.775	<0.001
standing duration (m)	12.10 ^a	5.85 ^c	9.59 ^b	0.605	<0.001
standing frequency	16.12 ^b	29.25 ^a	15.83 ^b	1.413	<0.001
sitting duration (m)	1.53	1.15	1.41	0.104	0.462
sitting frequency	26.43 ^a	15.38 ^c	20.93 ^b	1.701	<0.001

347 *Values are presented as mean \pm SEM duration (minutes), interval (minutes) and frequency (times/day) of behaviors observed.
348 For suckling and feeding behaviors, duration, interval, and frequency were recorded, whereas for postural behaviors, only
349 duration and frequency were evaluated. Different superscripts (^a, ^b, ^c) within a row indicate significant differences among groups
350 ($p < 0.05$, Tukey's HSD test). SEM = Standard Error of Mean. Group sample size (n = 5 per group).

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352 **Figure titles:**

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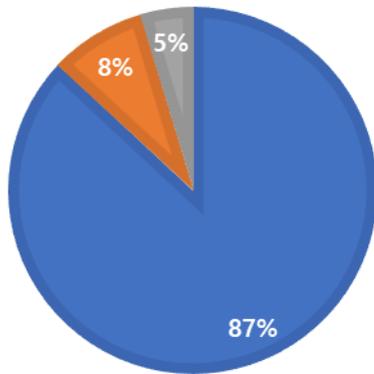
355 **Fig. 1. Process flow of methodology**

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NUMBER OF IMAGES

■ Training Set ■ Validation Set ■ Test Set

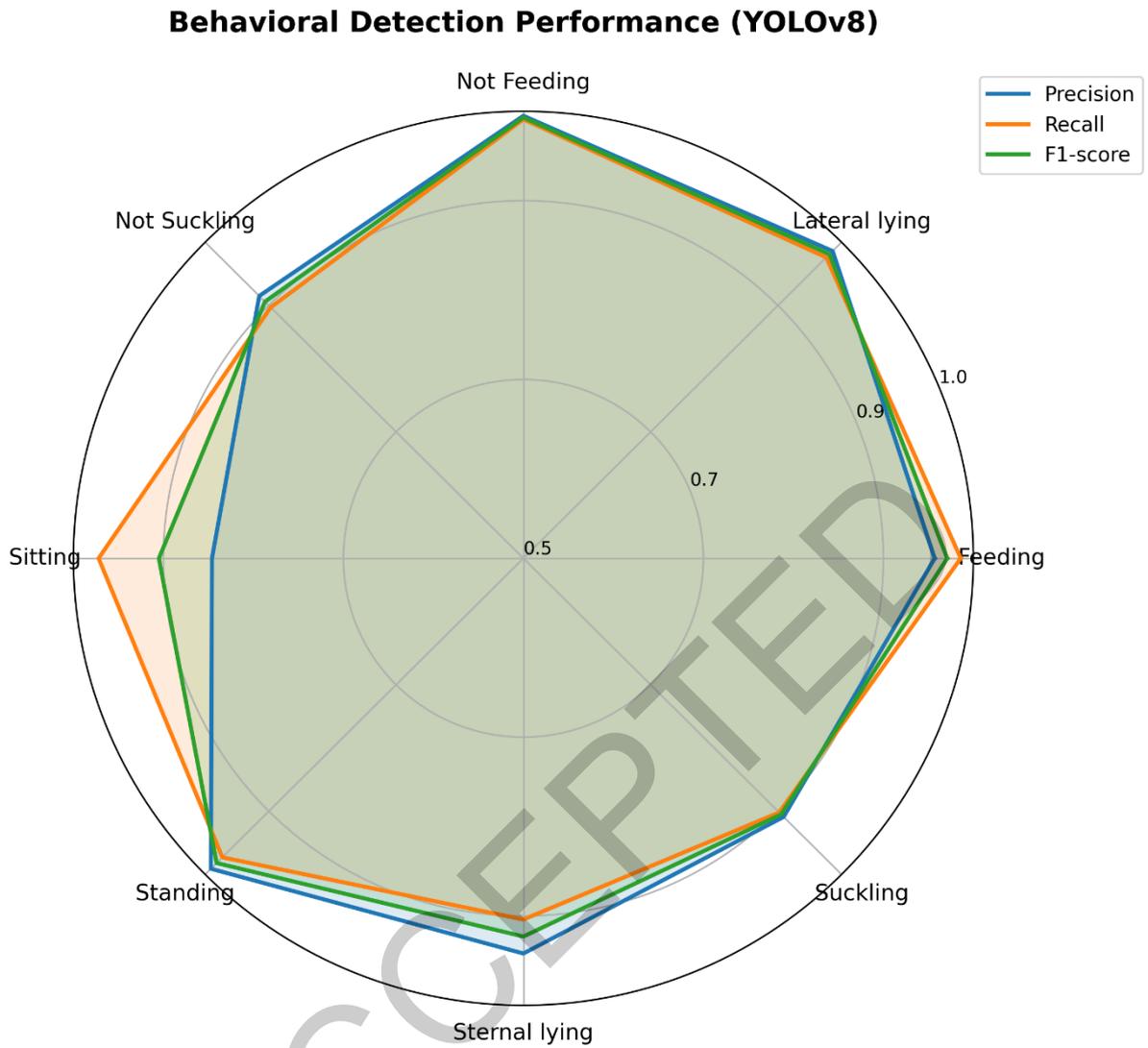


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359 **Fig. 2. Dataset split for model development**

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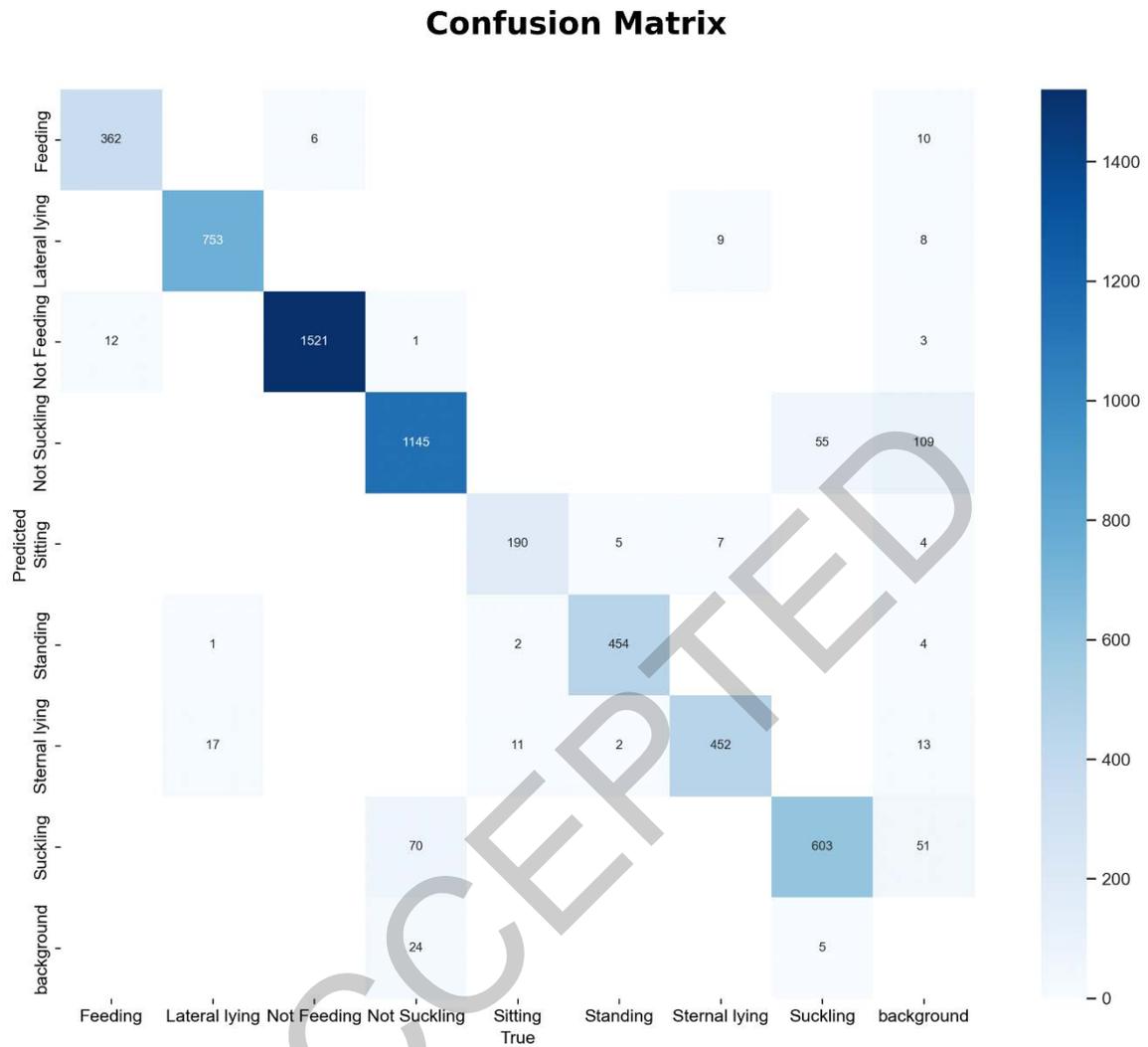
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362 **Fig. 3. Radar chart showing YOLOv8l detection performance across sow behavioral classes, evaluated**
 363 **using precision, recall, and F1-score.** The model demonstrates consistently high performance (≥ 0.90) across
 364 most classes, with the strongest results in not feeding, standing, and lateral lying, and slightly lower but reliable
 365 performance in sitting, not suckling, and suckling.

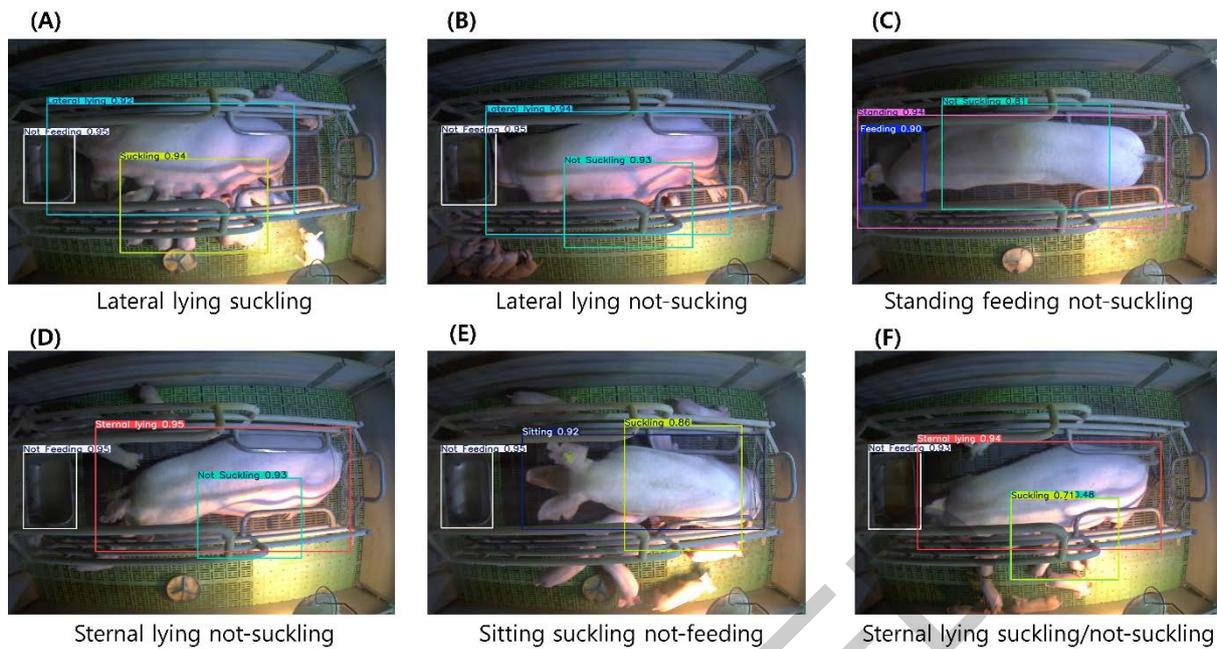
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368 **Fig. 4. Confusion matrix of YOLOv8 predictions for sow behaviors, with diagonal values showing correct**
 369 **classifications and color intensity indicating sample frequency.**
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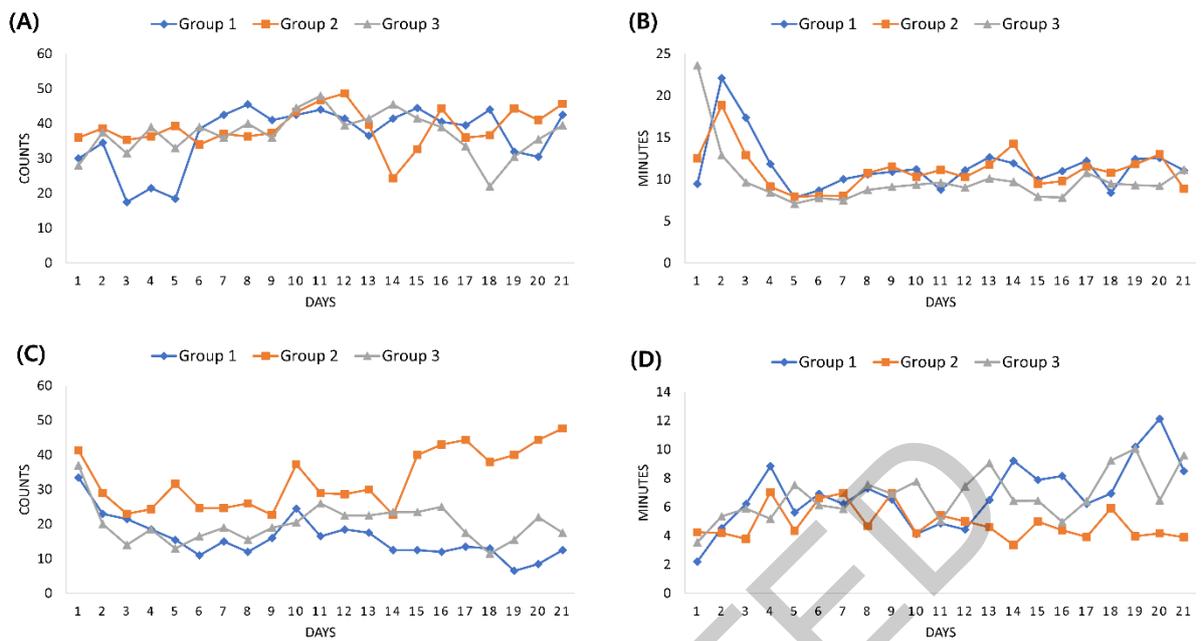
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Fig. 5. Representative images of sow behaviors detected using YOLOv8. (A) Lateral lying while suckling, (B) lateral lying not suckling, (C) standing while feeding but not suckling, (D) sternal lying not feeding, (E) sitting while suckling but not feeding, and (F) sternal lying with mixed suckling behavior (confusion in detection). Bounding boxes indicate the detected behavioral states.

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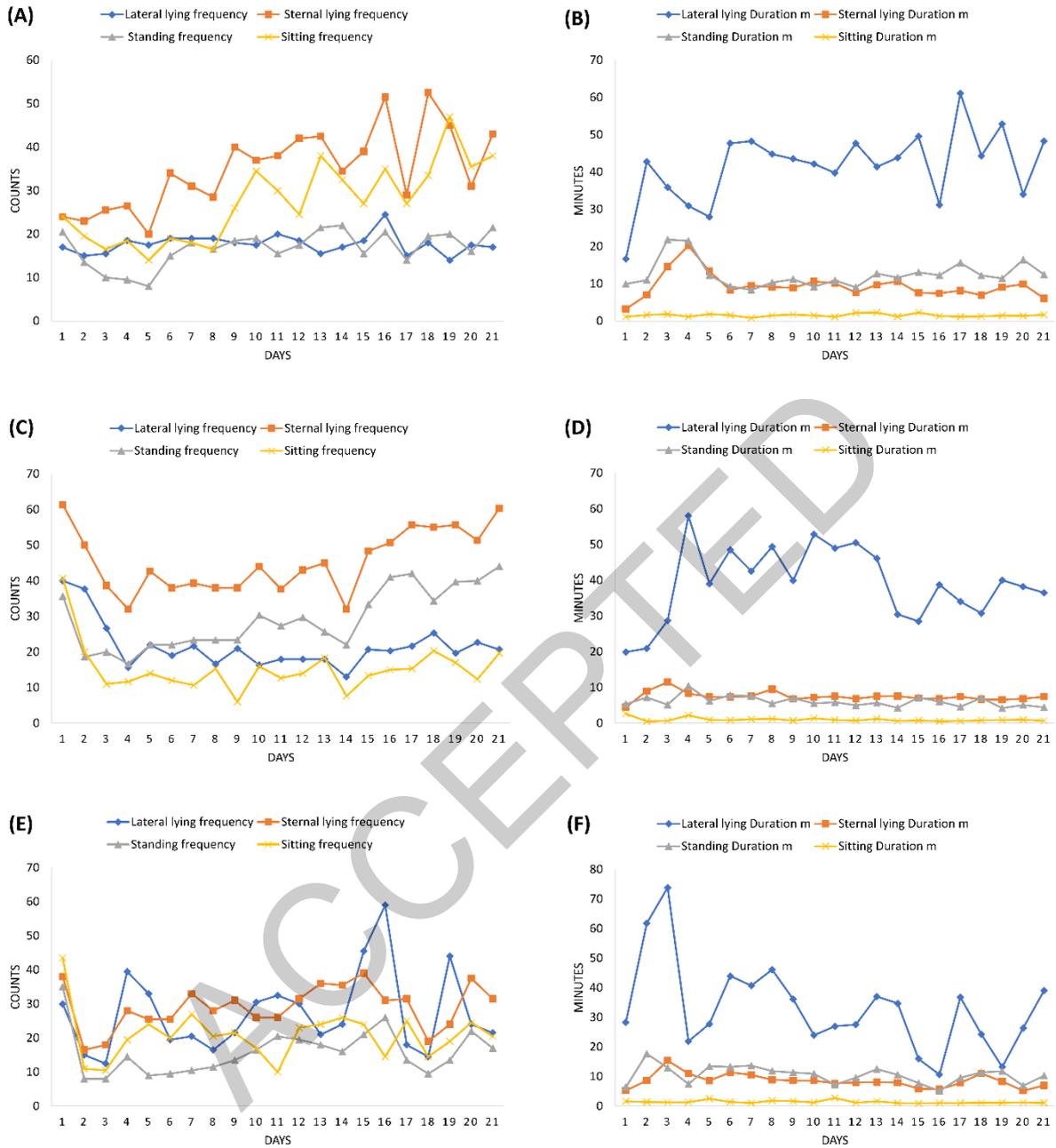


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Fig. 6. Daily trends of suckling and feeding behavior (frequency and duration) in three experimental groups of lactating sows. a) suckling frequency; b) suckling duration; c) feeding frequency; d) feeding duration.

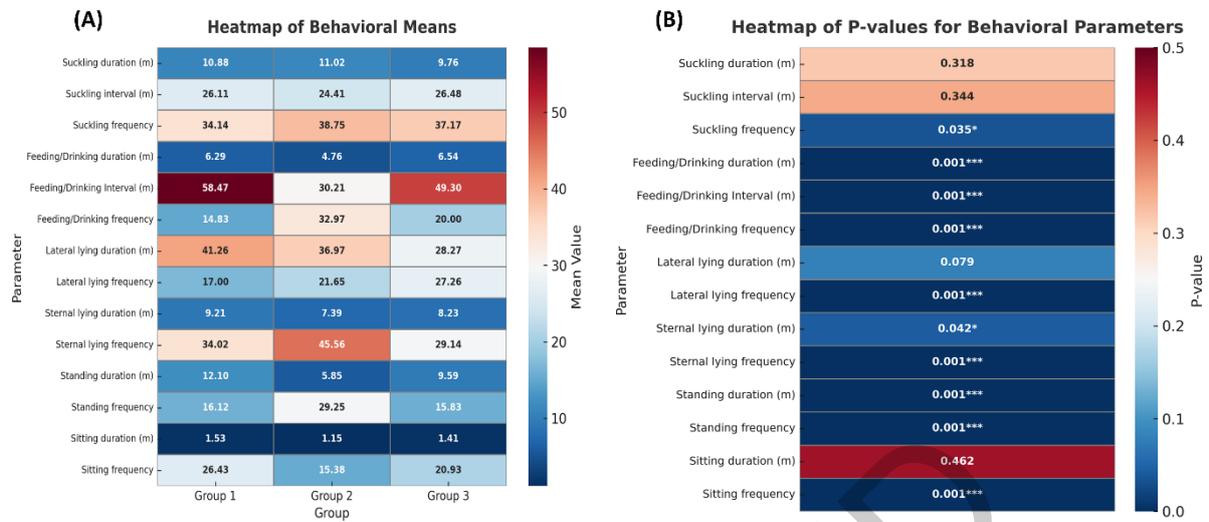
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Fig. 7. Daily trends of sow postural behaviors (frequency and duration) across experimental groups. a) postural frequency of Group 1, b) postural duration of group 1; c) postural frequency of Group 2, d) postural duration of group 2; e) postural frequency of Group 3, f) postural duration of group 3.



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Fig. 8. Heatmaps showing (A) mean values and (B) p-values of sow behavioral parameters across three experimental groups: Group 1 (5× daily feeding, air-conditioned), Group 2 (hourly feeding, air-conditioned), and Group 3 (hourly feeding, non-air-conditioned). Significance levels are color-coded: dark blue ($p \leq 0.001$) indicates highly significant differences (*), medium blue ($0.001 < p \leq 0.05$) indicates significant differences (or *), and red to light red ($p > 0.05$) indicates non-significant results (ns)**. Asterisks denote significance levels: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; ns = not significant.**