

1 Running head: Maternal behaviour and piglet survival

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3 Can we improve maternal care in sows? Maternal behavioural  
4 traits important for piglet survival in loose-housed sow herds

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15 <sup>1</sup>The authors wish to thank:

16 This study was financed by the Norwegian Research Council, Animalia, Nortura and Topigs  
17 Norsvin. The authors wish to thanks farmers that participated in the field survey.

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## ABSTRACT

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24 The primary objective of this survey was to investigate the relationship between qualitative  
25 maternal behavioural scores (nest building activities, sow communication and sow carefulness),  
26 piglet mortality and the number of weaned piglets on commercial farms with loose-housed  
27 lactating (Norsvin Landrace × Yorkshire) sows. Secondly, the impact of these scores on  
28 productivity compared to the physical condition of sows (movement disorders, body condition,  
29 and shoulder lesions) was assessed. Data on maternal care behaviours and physical condition were  
30 collected on 895 sows from 45 commercial farms. Farmers scored sows on their physical condition  
31 (movement disorder: MD, body condition: BCS, shoulder lesions: SL) and qualitative maternal  
32 care behaviours (nest building activities prior to farrowing: NBA; and sow communication: SC,  
33 and carefulness: SCR after farrowing, while sows were standing, moving and just before lying  
34 down). There was a low positive correlation between NBA and SC ( $r = 0.102$ ;  $P = 0.026$ ) and  
35 between NBA and SCR ( $r = 0.149$ ;  $P = 0.010$ ), but a high positive between SC and SCR ( $r =$   
36  $0.565$ ;  $P < 0.001$ ). Higher SC and SCR were associated with lower piglet mortality ( $P < 0.001$ ,  $P =$   
37  $0.013$ , respectively), and a greater number of weaned piglets were associated with higher scores  
38 for NBA ( $P = 0.009$ ), SC ( $P < 0.001$ ) and SCR ( $P = 0.009$ ). Maternal care behaviour had a greater  
39 impact on piglet mortality and the number of weaned piglets than sow physical condition (MD,  
40 BCS, SL). We tested 7 different models (combinations of behavioural scores) and compared their  
41 relative predictive accuracies using Akaike information criteria (AIC). The model including SC  
42 and SCR had the best predictive accuracy for piglet mortality/weaned piglets. There was between-  
43 sow variation in maternal care behaviours (SC and SCR) and both were unaffected by litter size.  
44 Since these behaviours were also easy to score for the farmers, combining SC and SCR have the

45 greatest potential to be tested in nucleus herds for calculation of genetic variation and heritability,  
46 and should be taken into account into future breeding programmes for sows.

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48 Keywords: nest building, piglet mortality, sow carefulness, sow communication, sow physical  
49 condition

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## INTRODUCTION

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54

55 Although modern maternal sow breeding programmes have resulted in more piglets weaned  
56 (Ocepek et al., 2017), piglet mortality is still a major welfare and economic issue as approximately  
57 20% of born piglets are dead or eventually died before weaning (Ocepek et al., 2016a). Piglet  
58 survival until weaning depends on interacting factors such as the physical environment (Andersen  
59 et al., 2007), management routines (Andersen et al., 2007, Rosvold et al., 2016), piglet viability  
60 (Pedersen et al., 2011), and maternal behaviour (Andersen et al. 2005; Ocepek and Andersen,  
61 2017). Promoting maternal care behaviours in sows kept loose during farrowing and lactation, can  
62 result in fewer piglet deaths, improve the welfare of pigs and, thus, contribute to more sustainable  
63 breeding.

64

65 Despite attempts to promote maternal care traits (Grandinson et al., 2003; Lovendahl et al., 2005;  
66 Vangen et al., 2005), there are methodological challenges with measuring traits accurately.

67 Recently, Ocepek and Andersen (2017) defined simple qualitative scorings of maternal care  
68 behaviours important for piglet survival (sow nest building, sow communication and carefulness).

69 To be useful under commercial conditions, these scores need to be simple and practical for farmers  
70 to be able to assess those traits on the farm.

71

72 The primary objective of this survey was to investigate the relationship between qualitative  
73 maternal behavioural scores (nest building activities, sow communication and sow carefulness),  
74 piglet mortality and the number of weaned piglets on commercial farms with loose-housed  
75 lactating (Norsvin Landrace × Yorkshire) sows. Secondly, the impact of these scores on  
76 productivity compared to the physical condition of sows (movement disorders, body condition,  
77 and shoulder lesions) was assessed.

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## 80 **MATERIAL AND METHODS**

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83 The present experiment was conducted in accordance with the laws and regulations controlling  
84 experiments and procedures on live animals in Norway and was approved by the Norwegian  
85 Animal Research Authority, following the Norwegian Regulation on Animal Experimentation Act  
86 of 1996.

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### 89 ***Farm selection and study design***

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92 Forty-five commercial pig farms were visited, meeting the following criteria: 1) had loose-housed  
93 lactating Norsvin Landrace × Swedish Yorkshire sows; 2) were located within the three major pig  
94 production regions in Norway (East, n = 16; West, n = 12; and Middle, n = 17); 3) differed in size  
95 (the numbers of litters born per year in each herd (Small = 30 – 110 litter per year (n = 14);  
96 Medium = 110 – 200 (n = 18); Large = 200 - ... (n = 13); and 4) kept farm production records in  
97 Ingris (The National Efficiency Control Database, administrated by Animalia (Norwegian Meat  
98 and Poultry Research Centre) and Norsvin (Norwegian Pig Breeding Association)). To investigate  
99 the importance of sow behavioural and physical characteristics, an on-farm registration form was  
100 designed. The registration form, together with instructions (see below – ‘On farm registration’),  
101 were sent to the farmers approximately one month before the onset of the study, which was  
102 followed up by a phone call and farm visitation by one of the trained researchers (MO or EMR).  
103 During the visit, additional information regarding environment and management routines on the  
104 farm was collected. The completed registration forms with behavioural and physical scores for  
105 each sow from one batch on the farm was sent to us, whereas the following production records for  
106 the same sows were collected from the Ingris database: parity number; number of live-born  
107 piglets; number of piglets that died after farrowing but before weaning; and number of weaned  
108 piglets (defined as number of the sow’s own live-born piglets plus the number of piglets fostered  
109 on minus the number of piglets fostered off and minus the number of piglets that died after  
110 farrowing but before weaning).

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### 113 *On farm registration*

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116 The on farm registration form included qualitative behavioural scores developed by Ocepek and  
117 Andersen (2017), and physical scores as tested in Ocepek et al. (2016a).

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120 ***Sow - physical scores.*** Sow physical condition scores (movement disorder (**MD**), body condition  
121 (**BCS**), shoulder lesions (**SL**)) were assessed while moving the sows from the gestation unit to the  
122 farrowing unit. MD were scored using a scale from 1 to 3 (1: normal, without visible movement  
123 problems; 2: marked movement disorders, walks slowly or limps in a stiff way; 3: severe  
124 movement problems, can hardly get up from a lying position or walk; Ocepek et al., 2016a). BCS  
125 was assessed using a grading scale from 1 to 5 and half points were used (Fig. 1). Presence of SL  
126 was assessed using a five-category scale. Score 0 was used when the shoulder region was intact,  
127 with healthy skin and without reddening or swelling. If SL were determined, scores from 1 to 4  
128 were used (Fig. 2).

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131 ***Sow - behavioural scores.*** Nest building score (**NBA**) was assessed after sows began to display  
132 preparation signs of farrowing (restless behaviour, nesting behaviour, and/or teats ejecting milk at  
133 hand milking) during morning or afternoon feeding within the last 24 hours before expected  
134 parturition. The NBA score included rooting (nosing in the nest building material on the floor),  
135 pawing (leg in the nest building material on the floor), carrying nest building material, and  
136 chewing nest building material while the sow was active (standing or moving around) using a  
137 scale from 1 to 3 as presented in table 1. Sow communication (**SC**, sniffing, grunting, and  
138 nudging) and sow carefulness (**CSR**) was assessed immediately after morning or afternoon feeding  
139 on day one or two postpartum while sows changed position, moved around and at the moment the

140 sow was about to lie down. Both scores, SC and SCR, were assessed with a scale from 1 to 4 as  
141 presented in table 1.

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#### 144 ***Housing and management routines***

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147 ***Housing.*** According to the Norwegian animal welfare regulations, gestation stalls and farrowing  
148 crates are banned ([www.lovdata.no](http://www.lovdata.no)). During pregnancy, all sows must be kept in group-housing  
149 systems from four weeks after service. From day three before expected parturition, sows shall have  
150 access to nest building material. During farrowing and lactation, sows must be kept loose in a  
151 farrowing pen larger than 6.0 m<sup>2</sup> with a width of more than 1.8 m, allowing the sow to turn around.  
152 Plenty of the litter should be on the pen floor. Furthermore, the farrowing pen must be designed in  
153 a way that provides sufficient space for the sows during farrowing (and for farrowing assistant if  
154 needed) and a separate microclimate for the piglets that is inaccessible to the sow. Exceptions  
155 regarding confinement can be made for restless or aggressive sows but only for one week (from  
156 parturition until seventh day afterwards) in crates longer than 2.0 m with a width of 0.7 to 0.8 m,  
157 depending on the sow's size.

158

159 The mean size of the farrowing pens in the 45 farms was  $7.5 \pm 0.1$  m<sup>2</sup> (range 6.0 - 10.5 m<sup>2</sup>), with a  
160 mean width of  $2.3 \pm 0.0$  (range 1.9 - 3.4) and none of the sows were crated at any time. Each sow  
161 was on average provisioned with  $2.2 \pm 0.32$  kg (range 0.1 - 10 kg) of nest building material.

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164 **Management routines.** The farms can be divided into four management groups (farms without  
165 routines, farms conducting more than two contacts per day with the sows (defined as touching,  
166 talking to and/or being present near the sow in the farrowing pen), farms performing three  
167 management routines at farrowing (defined as farmer presence at 80 – 100 % of farrowing's,  
168 drying and massaging newborn piglets, and practicing split suckling) and farms conducting both,  
169 contact with the sows and all management routines (Rosvold et al., 2016). All groups were  
170 included in the present study. Out of 45 farms, 10 farms did not perform any of the four  
171 management routines, 11 farms had contact with sows more than 2 times per day, 11 farms  
172 performed the three mentioned routines at farrowing, and 13 farms combined contact and the  
173 routines.

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#### 176 ***Collected data***

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179 The data contained information on 895 sows out of which 20 sows without BCS, 17 without MD,  
180 18 without SL, 15 without NBA, 3 without SC.

181

182 To facilitate subsequent calculations, BCS scores were transformed into values from 1 to 3; thin  
183 (1.0-2.5), normal (3.0-3.5), fat (4.0-5.0). Around 13% percent of the sows were thin, 63 % of the  
184 sows were categorised as normal and 24 % of the sows were classified as fat. Approximatively,  
185 93% of the sows had no signs of movement disorders, 6% were slower (limping, score 2), and less  
186 than 1% had severe movement problems (score 3). Furthermore, around 93% of the sows had  
187 healthy skin without SL, more than 6% were classified with initial shoulder injuries and less than  
188 1% with moderate skin lesions (score 2) as well as serious shoulder lesions (score 3). As there



189 were very few higher scores for MD and SL, both traits were categorized into two classes (sows  
190 without MD and/or SL = class 1; sow with MD and/or SL = class 2).

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### 193 *Statistical analysis*

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196 Descriptive statistics were presented as arithmetic mean and SE. Statistical analyses were  
197 performed using SAS 9.4 statistical software program (SAS Institute. Inc., Cary, NC).

198

199 The effects of physical condition (MD, BCS, SL) as fixed effects (class variables) on behavioural  
200 scores (NBA, SC, SCR) were analysed using the GLIMMIX procedure (Multinomial distribution).  
201 Parity and litter size were included as continuous variables. Farm was specified as a random effect.

202

203 Polychoric correlation coefficients were used when testing the relationships between sow  
204 behavioural scores (NBA, SC, SCR).

205

206 The effect of behavioural (NBA, SC, SCR) and physical (MD, BCS, SL) scores as fixed class  
207 variables on piglet mortality and the number of weaned piglets were analysed using a mixed model  
208 (Proc Mixed). Farm (class variable) and parity and litter size (continuous variables) were included  
209 in the model. Sow nested within the farm was specified as a random effect.

210

211 To find the best combination of behavioural scores (7 combinations of defined scores), the model  
212 with the best relative predictive accuracy for piglet mortality/weaned piglets was determined using

213 the Akaike information criterion (AIC). The AIC values were transformed to Akaike weights to  
214 provide the relative probability of each model having the best predictive accuracy.

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## RESULTS

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### 220 *Descriptive data*

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223 The mean number of sows per farm in a farrowing batch was  $20.0 \pm 0.9$  (range 10 - 31), and sow  
224 parity ranged from 1 to 9, with 33.9 % of the sows in first, 23.3 % in second, 18.7 % in third, 12.5  
225 % in fourth, 7.1 % in fifth, 2.3 in sixth, 1.6 % in seventh, 0.3 % in eight, and 0.3 % in ninth parity.

226 The mean number of piglets at birth was  $14.1 \pm 0.1$  (range 3 - 23) and at weaning  $11.6 \pm 0.1$  (Fig.  
227 3a), whereas the overall mean postnatal mortality was  $16.3 \pm 0.5\%$  (Fig 3b).

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229

### 230 *Sow behaviour*

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232

233 ***Nest building behaviour score (NBA)***. During the last 24 hours before parturition, 22.8 % of the  
234 sows showed no nest building activities (score 1), whereas 28.0 % of the sows spent the majority  
235 of their time on NBA (score 3; Fig. 4a). There was no significant effect of parity, nor litter size on  
236 NBA (Table 2). Sows with MD had a lower NBA than sows without (Table 2; Fig. 5a). Sows with  
237 normal BCS had higher NBA compared to thin or fat sows (Table 2; Fig. 6). NBA was unaffected  
238 by SL (Table 2).

239

240

241 ***Sow communication score (SC)***. While 34.9 % of the sows communicated every time they  
242 changed position or moved around (score 4), 17.0 % of the sows communicated less than 50% of  
243 the time they changed position or moved around (score 2; Fig. 4b). There was a negative  
244 relationship between parity and SC (Table 2; Fig. 7a). SC was not significantly affected by litter  
245 size (Table 2). Sows with MD had lower SC than sows without (Table 2; Fig. 5b). SC was not  
246 significant effect by BCS nor SL (Table 2).

247

248

249 ***Sow carefulness score (SCR)***. More than half of the sows (50.1 %) were classified as attentive,  
250 careful and protective in more than 50% of the events when they changed position or moved  
251 around (score 3), while 30.3 % of the sows were categorized as attentive, careful and protective  
252 every time they changed position or moved around (score 4; Fig. 4c). There was a negative  
253 relationship between parity and SCR (Table 2; Fig. 7b). SCR was not significantly affected by  
254 litter size (Table 2). Sows with MD had lower SCR than sows without (Table 2; Fig. 5c). SCR was  
255 not significantly affected by BCS nor SL (Table 2).

256

257

258 ***Interrelationship between behavioural scores.*** There was a low positive correlation between NBA  
259 and SC ( $r = 0.102$ ;  $P = 0.026$ ) and SCR ( $r = 0.149$ ;  $P = 0.010$ ) and a high positive correlation  
260 between SC and SCR ( $r = 0.565$ ;  $P < 0.001$ ).

261

262

### 263 **Production parameters**

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265

266 ***Postnatal mortality.*** There was no significant effect of NBA on postnatal mortality (Table 3).  
267 Sows with higher SC had lower postnatal mortality (Table 3; Fig. 8a). The higher the SCR, the  
268 lower the postnatal mortality (Table 3; Fig. 8b). There was no significant effect of parity on  
269 postnatal mortality (Table 3). Mortality significantly increases in larger litters (Table 3; Fig. 9).  
270 Postnatal mortality was not significantly affected by sow physical condition (MD, BCS, and SL,  
271 Table 3). There was significant difference in postnatal mortality between farms (Table 3).

272

273

274 ***Number of weaned piglets.*** A high degree of NBA (Table 3; Fig. 10a), SC (Table 3; Fig. 10b) and  
275 SCR (Table 3; Fig. 10c) was associated with more piglets weaned. There was no significant effect  
276 of parity on number of weaned piglets (Table 3). More piglets were weaned in larger litters (Table  
277 3; Fig. 11). Number of weaned piglets was not significantly affected by MD, BCS, and SL (Table  
278 3). There was a significant difference between farms in number of weaned piglets (Table 3).

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280

281 *Predictive accuracy of behavioural scores for production parameters.* Out of the 7 models (all  
282 combinations of defined scores), we found that model 6 including SC and SCR had the best  
283 predictive accuracy (lowest AIC values and highest AIC weights) for piglet mortality/weaned  
284 piglets (Table 4).

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286

## 287 **DISCUSSION**

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289

290 In accordance with recent experimental study that documented a clear relationship between  
291 maternal behavioural scores and piglets survival (Ocepek and Andersen, 2017), we succeed in  
292 finding similar results on 45 commercial farms with 895 LY sows. While an increased nest  
293 building activity (NBA) resulted in an increased number of weaned piglets, sow communication  
294 (SC) and carefulness (SCR) had the strongest effects on both mortality and the number of weaned  
295 piglets in loose-housed sows. In fact, the maternal behavioural scores had a stronger impact on  
296 piglet survival per se than physical traits such as movement disorders (MD), body condition score  
297 (BCS) and lesion score (SL). However, these physical traits along with parity, influenced the  
298 behavioural scores, indicating that the physical condition of the sow will affect maternal skills.

299

300 Our results showed that farmers understood the qualitative scoring system just by verbal advice  
301 (without on-site pre-training) and that the behavioural scores were important predictors for piglet  
302 survival. Using model selection, our results showed that a combination of SC and SCR had the

303 best predictive accuracy for determining levels of piglet mortality/weaned piglets. Thus, these  
304 maternal care behaviours (SC and SCR) could be implemented in the breeding goal as a novel  
305 approach to improve piglet survival and thus ensure future sustainable pig breeding.

306  
307 Sows that communicated to large extent with their piglets and were careful with their own  
308 movements when piglets were in close proximity (i.e. high scores for SC and SCR), had  
309 substantially lower postnatal mortality and weaned more piglets. In Ocepek and Andersen (2017),  
310 sows with higher SC and SCR were capable of weaning more piglets mainly due to fewer deaths  
311 from maternal crushing. Additionally, higher SC was associated with a lower proportion of starved  
312 piglets. Starvation and crushing constitutes more than 60% of all piglet deaths in loose-hosed sows  
313 (Andersen et al., 2006; Vasdal et al., 2011; Ocepek et al., 2016b). Our study suggests that there  
314 could be a great potential in selecting for maternal care directly. Sows with SC score 4 (highest) as  
315 opposed to 1 (lowest) had almost 37% lower mortality and 15% more piglets weaned, while the  
316 respective values for SCR were 15% and 8%. The trend of improving survival continued between  
317 scores 4 and 2: sows with SC scores 4 compared to 2 had 35% lower mortality and 8% more  
318 weaned piglets, whereas the respective values for SCR were 41% and 12%.

319  
320 Another important finding was that SC and SCR scores were highly correlated, replicating results  
321 in Ocepek and Andersen (2017). It appears that SC and SCR both represent good measures or  
322 indicators of maternal care behaviour during the first few days after parturition when piglet losses  
323 are most likely to occur. As sows establish contact with their piglets, through olfactory (sniffing),  
324 auditory (grunting) and tactile (nudging) communicative cues, they can locate the piglets' position.  
325 From an evolutionary point of view, this mechanism aids sows to keep the piglets in close  
326 proximity, protecting them from danger. Awareness of the piglets' presence helps the sow to

327 become careful, attentive and protective around the piglets (without trampling on them or lie on  
328 them). Thus, stimulating sow motivation to care for her young is crucial for ensuring the future  
329 welfare and sustainability of pig production. This can be brought about through selecting for these  
330 particular maternal traits and by stimulating the sow to become more attentive through  
331 environmental factors (i.e. nest building material, good handling to prevent fear etc.). The simple  
332 scoring, the large individual variation and stability of the traits irrespective of litter size and breed  
333 (e.g. three different breeds show similar results: Ocepek and Andersen, 2017) make them  
334 particularly suited for selection.

335

336 Maternal care scores (SC and SCR) also decreased with parity. Thus, sows in earlier reproductive  
337 life appear to show better maternal care behaviour. This is not surprising, because breeding goals  
338 have emphasised greater maternal investment earlier in life (Canario et al., 2009; Ocepek et al.,  
339 2016a). A high maternal investment early in life has a substantial future cost in that it reduces the  
340 residual reproductive value of the sow, compromising longevity. We would like to pinpoint the  
341 importance of selection during the sows' reproductive live, rather than focus on the first two litters.

342

343 Furthermore, sows at farrowing might respond to suboptimal physical conditions of the sow by  
344 reducing maternal care. Here, we showed that if sows had problems with moving, they had lower  
345 scores for maternal care (i.e. SC and SCR) than sows without movement problems. It is, therefore,  
346 crucial to have healthy sows while promoting maternal care behaviours.

347

348 Even though sows have the internal motivation to prepare a proper nest for newborn piglets, this is  
349 mediated by their physical condition. We found that MD and BCS, two physical conditions,  
350 influenced NBA. Sows with movement disorders or sows that are classified as thin or fat invest

351 less time in NBA. Suboptimal MD or BCS causes difficulties for sows to lie down and stand up, as  
352 well as to move around (Bonde et al., 2004). This result highlights the necessity of making sure  
353 that the sow is healthy and in good physical condition before farrowing to ensure so that maternal  
354 behaviour can proceed as optimal as possible.

355  
356 Piglet survival was partly affected by NBA. Higher NBA was associated with more piglets  
357 weaned, although this higher NBA was not clearly related to lower mortality. In Ocepek and  
358 Andersen (2017), sows that engaged in more NBA also weaned more piglets as fewer piglets died  
359 from maternal crushing. However, in their study, sows had ad libitum access to nest building  
360 material prior to parturition, while in our study access varied from 0.1 to 10.0kg. The performance  
361 of NBA is related to environmental factors (i.e. provision of nest building material). If amount of  
362 relevant external stimuli is insufficient or the timing before farrowing is wrong nest building  
363 activity may fail to make the sow relaxed and become attentive towards her young (e.g. Wischner  
364 et al., 2009). Although, there was between-sow variation in NBA scores and NBA was positively  
365 correlated with the other two behavioural scores as well as unaffected by parity and litter size,  
366 NBA had a minor effects on piglet survival under commercial conditions. On farms we cannot be  
367 sure that sufficient amount of nest building material is provided at the right time.

368  
369 Finally, we identified impact of maternal care behaviours on productivity compared to physical  
370 conditions of the sows. Our results showed that maternal care behaviours are more direct  
371 predictors of piglet survival than the physical condition of the sow. However, suboptimal physical  
372 conditions at farrowing can reduce maternal care, indicating that physical condition is likely  
373 related to productivity through its effect of the expression of maternal care. Thus, improving sows



374 physical condition at farrowing promotes maternal care behaviours important for determining  
375 piglet survival.

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## CONCLUSSION

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380

381 This study investigated the relationships between qualitative scores of maternal care behaviours  
382 (NBA, SC, SCR), sow physical condition variables (MD, BCS, SL) and piglet survival under  
383 commercial conditions. We found that farmers were able to implement the qualitative scoring  
384 system, and that maternal care behaviours were more predictive of piglet survival (low piglet  
385 morality and more weaned piglets) than physical condition of the sow. In particular, our results  
386 showed that a combination of SC and SCR had the best predictive accuracy for piglet  
387 mortality/weaned piglets. The large individual variation in SC and SCR, the fact that they were not  
388 affected by litter size, and easy to record for the farmer, indicates that they are suitable behavioural  
389 parameters for testing in nucleus herds to be implemented in the future breeding programme.

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- 447

448 Table 1. Scale definition of qualitative behavioural scores (reproduced by Ocepek and Andersen, 2017)

449

Behavioral scores	Definition of scale values
NBA <sup>1</sup>	1 - No nest building events observed
	2 - Less than 50 % of the active time spent nest building
	3 - More than 50 % of the active time spent nest building
SC <sup>2</sup>	1 - No events with communication, when the sow change position or move around
	2 - The sow communicates less than 50% of the event when she changes position or move around
	3 - The sow communicates more than 50% of the event when she changes position or move around
	4 - The sow communicates every event she changes position or move around
SCR <sup>3</sup>	1 - No events when sow is observed showing attentive, careful and protective behaviours
	2 - The sow is attentive, careful and protective less than 50% of the events when she changes position or move around
	3 - The sow is attentive, careful and protective more than 50% of the events when she changes position or move around
	4 - The sow is attentive, careful and protective every time she changes position or move around

450 <sup>1</sup>NBA = Nest building activities score

451 <sup>2</sup>SC = Sow communication score

452 <sup>3</sup>SCR = Sow carefulness score

453

454

455 Table 2. Influence of fixed effects on qualitative behavioural scores

456

Sow behavioural score	Parity		Litter size		MD <sup>1</sup>		BCS <sup>2</sup>		SL <sup>3</sup>	
	F <sub>1, 805</sub>	P	F <sub>1, 805</sub>	P	F <sub>1, 805</sub>	P	F <sub>2, 805</sub>	P	F <sub>1, 805</sub>	P
NBA <sup>4</sup>	0.2	ns	0.0	ns	6.3	0.012	3.8	0.022	0.2	ns
SC <sup>5</sup>	14.3	<0.001	0.6	ns	3.7	0.050	1.5	ns	2.0	ns
SCR <sup>6</sup>	15.7	<0.001	1.5	ns	7.7	0.006	0.0	ns	0.3	ns

457 <sup>1</sup>MD = Movement disorder score

458 <sup>2</sup>BCS = Body condition score

459 <sup>3</sup>SL = Shoulder lesions score

460 <sup>4</sup>NBA = Nest building activities score

461 <sup>5</sup>SC = Sow communication score

462 <sup>6</sup>SCR = Sow carefulness score

463

464 Table 3. Influence of fixed effects on piglet mortality and survival trait

465

Fixed effects	Mortality, %		Weaned piglets, n	
	F ( )	P	F ( )	P
NBA <sup>1</sup>	2.8 (1, 799)	ns	6.8 (1, 799)	0.009
SC <sup>2</sup>	13.7 (1, 799)	<0.001	14.0 (1, 799)	<0.001
SCR <sup>3</sup>	6.2 (1, 799)	0.013	6.8 (1, 799)	0.009
Parity	3.1 (1, 799)	ns	3.3 (1, 799)	ns
Litter size	695.1 (1, 799)	<0.001	42.1 (1, 799)	<0.001
MD <sup>4</sup>	0.1 (1, 799)	ns	0.1 (1, 799)	ns
BCS <sup>5</sup>	2.5 (2, 799)	ns	0.7 (2, 799)	ns
SL <sup>6</sup>	0.5 (1, 799)	ns	0.5 (1, 799)	ns
Farm	2.9 (43, 799)	<0.001	2.7 (43, 799)	<0.001

466 <sup>1</sup>NBA = Nest building activities score

467 <sup>2</sup>SC = Sow communication score

468 <sup>3</sup>SCR = Sow carefulness score

469 <sup>4</sup>MD = Movement disorder score

470 <sup>5</sup>BCS = Body condition score

471 <sup>6</sup>SL = Shoulder lesions score

472

473 Table 4. Predictive accuracy differences between different combination of behavioural scores for  
 474 piglet mortality and survival traits

475

Model	Postnatal mortality, %	AIC <sup>1</sup>	AIC weights <sup>2</sup> (%)
1	NBA <sup>3</sup>	3787.3	0.0
2	SC <sup>4</sup>	3735.5	0.0
3	SCR <sup>5</sup>	3738.5	0.0
4	NBA & SC	3735.9	0.0
5	NBA & SCR	3738.2	0.0
6	SC & SCR	3714.5	58.7
7	NBA, SC & SCR	3715.2	41.3

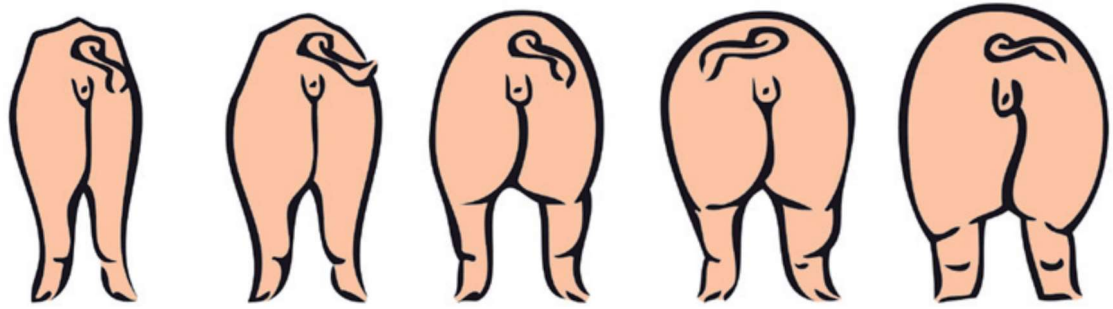
  

Model	Weaned piglets, n	AIC <sup>1</sup>	AIC weights <sup>2</sup> (%)
1	NBA	3896.4	0.3
2	SC	3889.0	10.8
3	SCR	3887.8	19.8
4	NBA & SC	3890.2	6.0
5	NBA & SCR	3889.0	10.9
6	SC & SCR	3886.7	34.3
7	NBA, SC & SCR	3888.0	17.9

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<sup>1</sup>AIC = Akaike information criterion (smaller value, better predictive accuracy)  
<sup>2</sup>AIC weights = Akaike weights (higher percentage, higher predictive accuracy)  
<sup>3</sup>NBA = Nest building activities score  
<sup>4</sup>SC = Sow communication score  
<sup>5</sup>SCR = Sow carefulness score













Score	1	1.5	2	2.5	3	3.5	4.0	4.5	5.0
Definition	Very thin, with hips and backbone very prominent without fat covering hips and backbone	Thin, hip bones and backbone are easily felt without any pressure on the palms	Normal-good, it takes firm palm pressure to feel the hip bones and backbone				Fat; impossible to feel the bones at all, even when pressed with palm		Very fat, so fat that it is impossible to feel the hip bones and backbone even by pushing down with a single finger

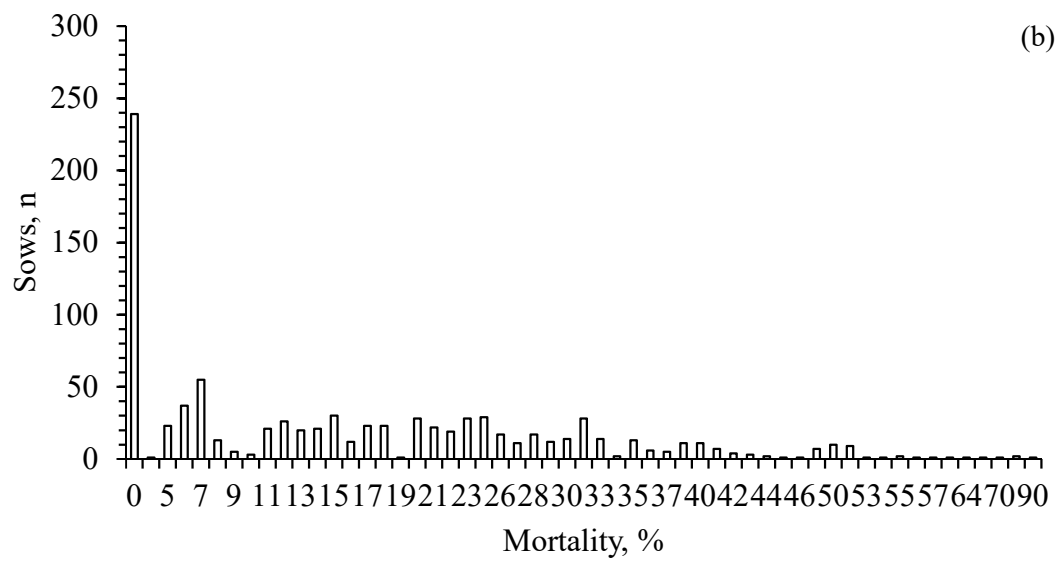
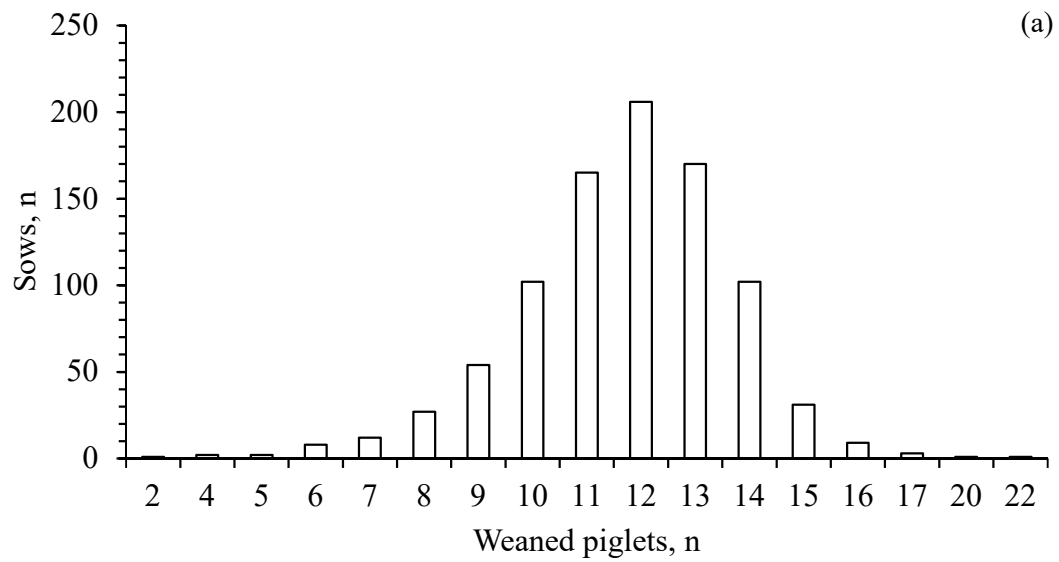
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483 Fig. 1: Body condition scores (Animalia, 2014)

<b>Score 1</b>		
Initial stage, mild lesions of the skin, including reddening or swelling or minor non-bleeding patches/wounds (diameter < 2cm)		
<b>Score 2</b>		
Moderate skin lesions, the wound includes the entire skin thickness and causes bleeding; crusts are common (diameter 2-3 cm), and the amount of granulation tissue is very moderate		
<b>Score 3</b>		
Serious lesions, these lesions include subcutaneous tissue, but not bone; swelling around the wound and production of granulation tissue are common (diameter 3-5 cm)		
<b>Score 4</b>		
Very serious lesions, serious injury involving the scapula bone. The tissue around the lesion is thickened and often adherent to the underlying bone, granulation tissue is common. The wound has commonly a diameter of 5 cm or more		

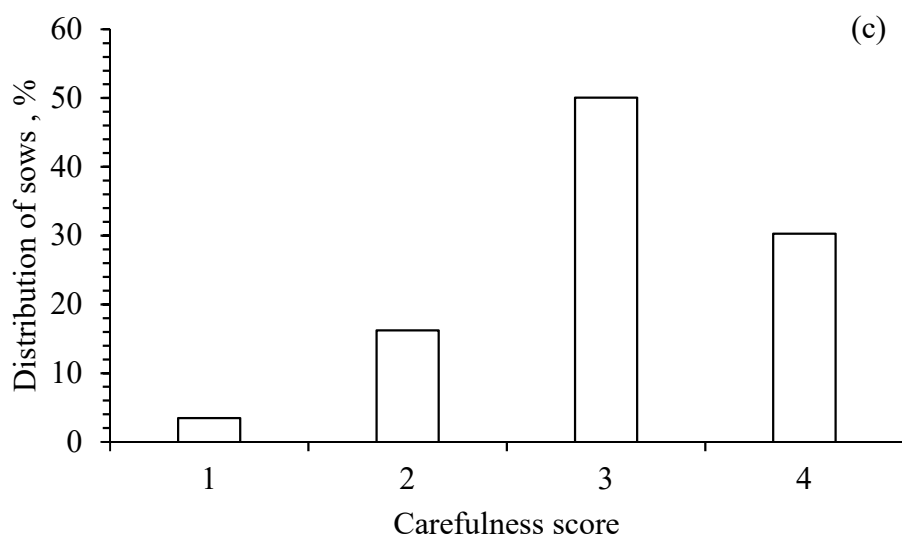
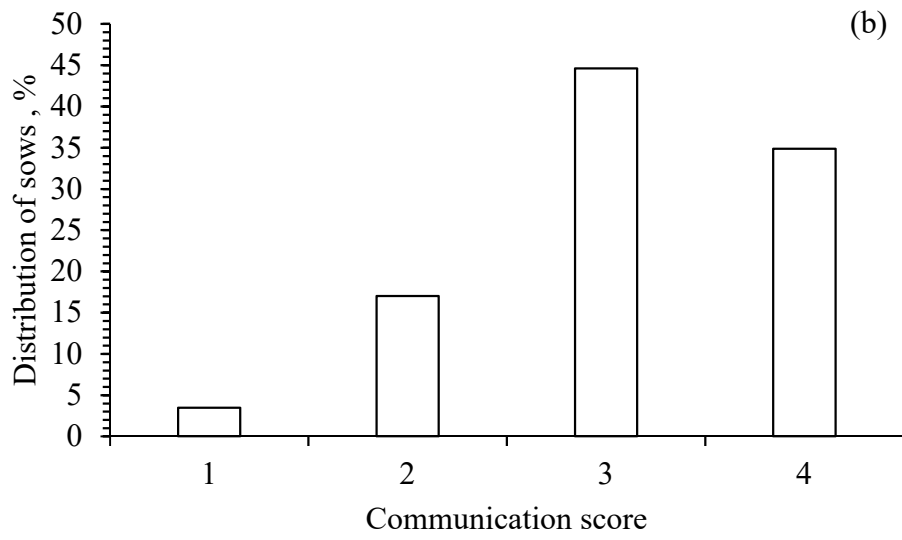
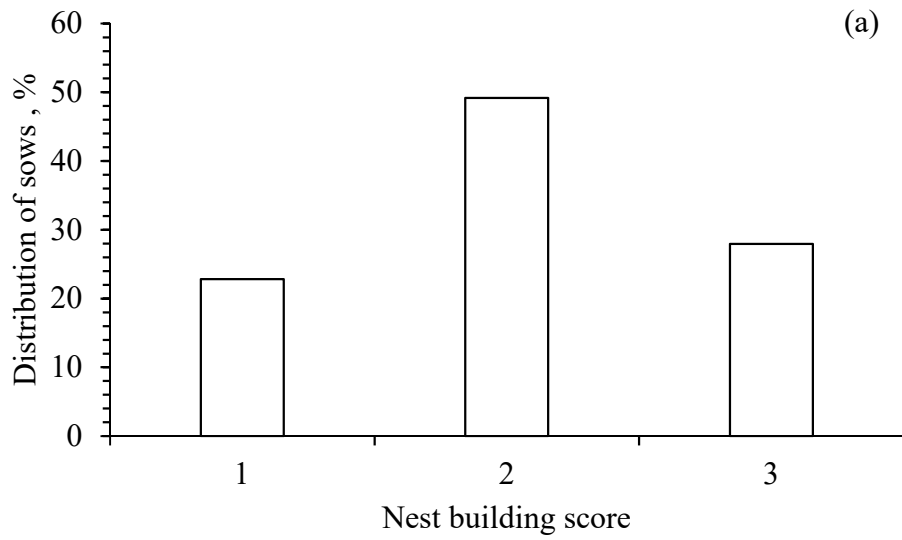
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485 Fig. 2: Shoulder lesion scores (Animalia, 2014)

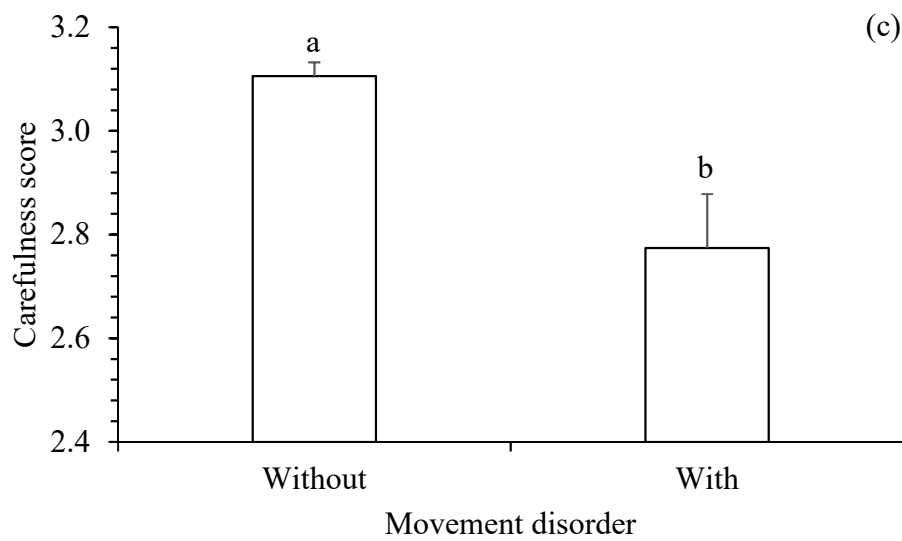
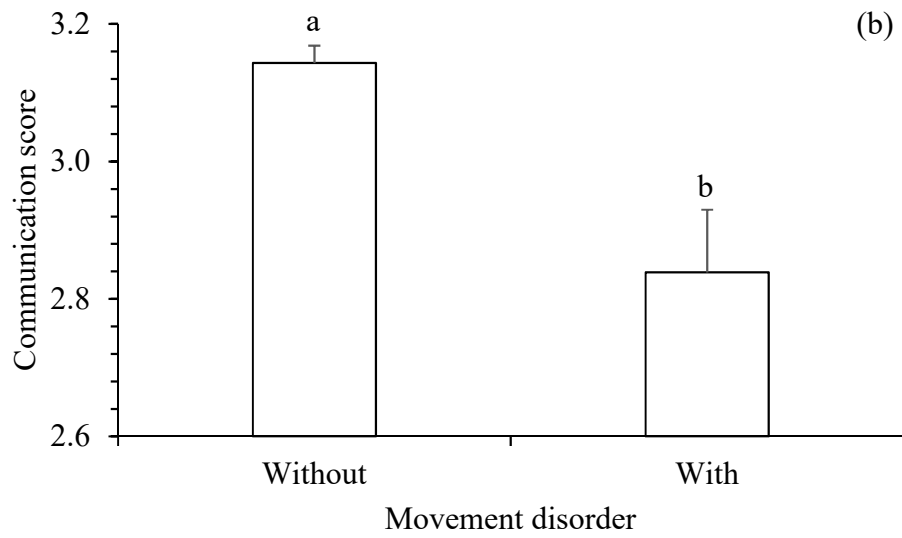
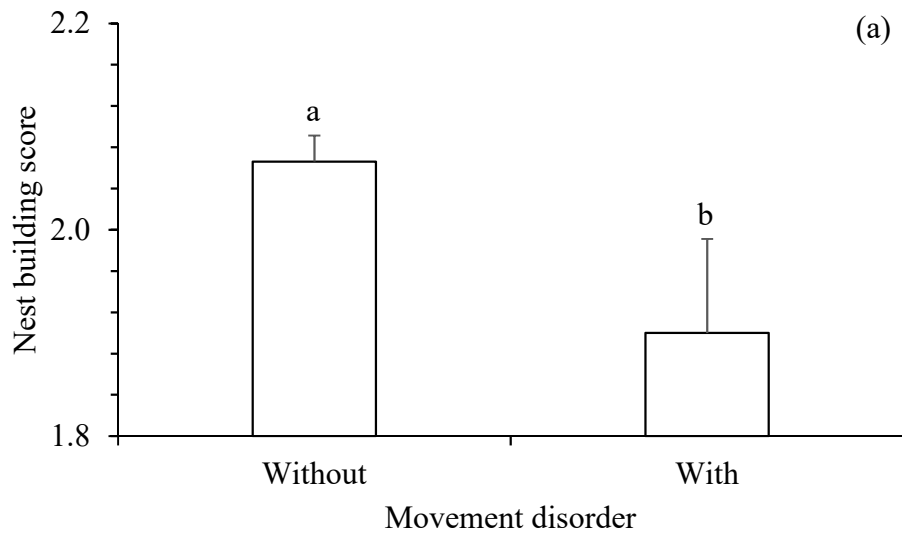


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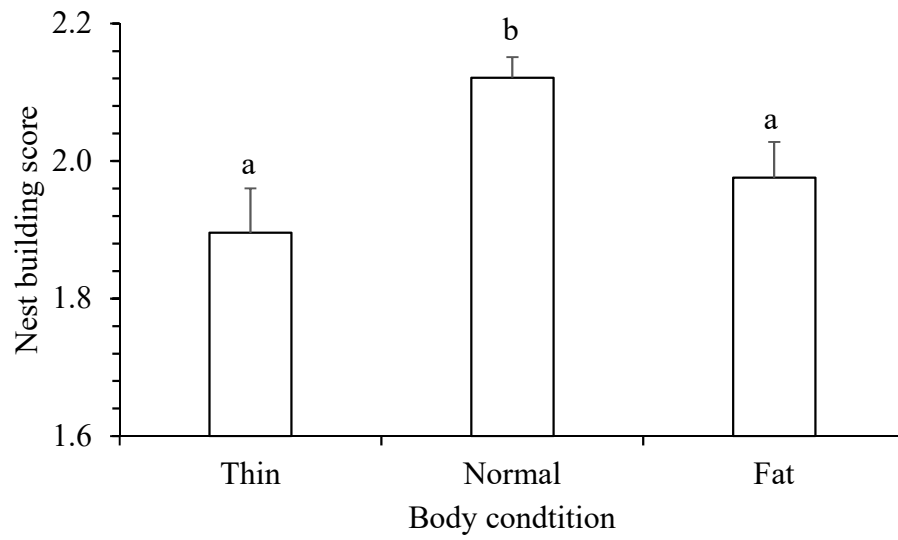
487 Fig. 3: Distributions of sows in relation to; (a) number of weaned piglets; (b) piglet mortality



488 Fig. 4: Distributions of sows in relation to behavioural scores: (a) nest building; (b) sow  
 489 communication to piglets; (c) sow carefulness to piglets

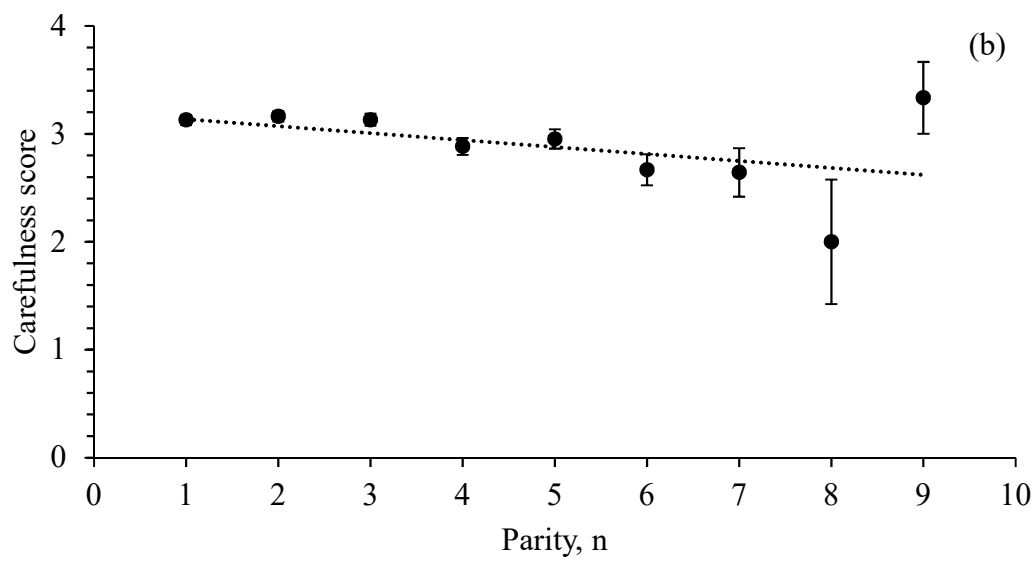
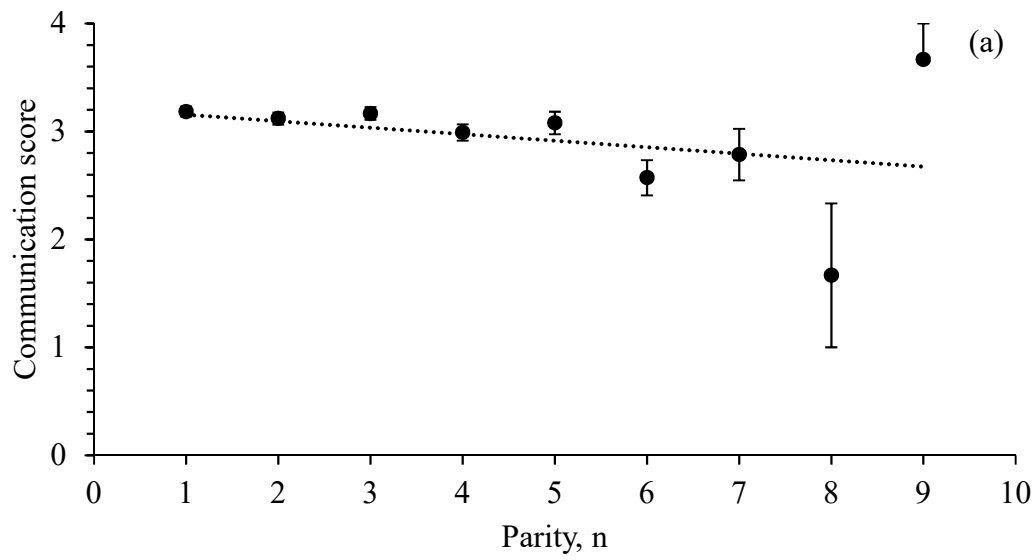


490 Fig. 5: Relation between movement disorder and behavioural scores: (a) nest building ( $F_{1, 805} = 6.3$ ;  $P =$   
 491 0.012); (b) sow communication to piglets ( $F_{1, 805} = 3.7$ ;  $P = 0.050$ ); (c) sow carefulness to piglets ( $F_{1, 805}$   
 492  $= 7.7$ ;  $P = 0.006$ )



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Fig. 6: Relation between body condition score and nest building score ( $F_{2, 805} = 3.8$ ;  $P = 0.022$ )

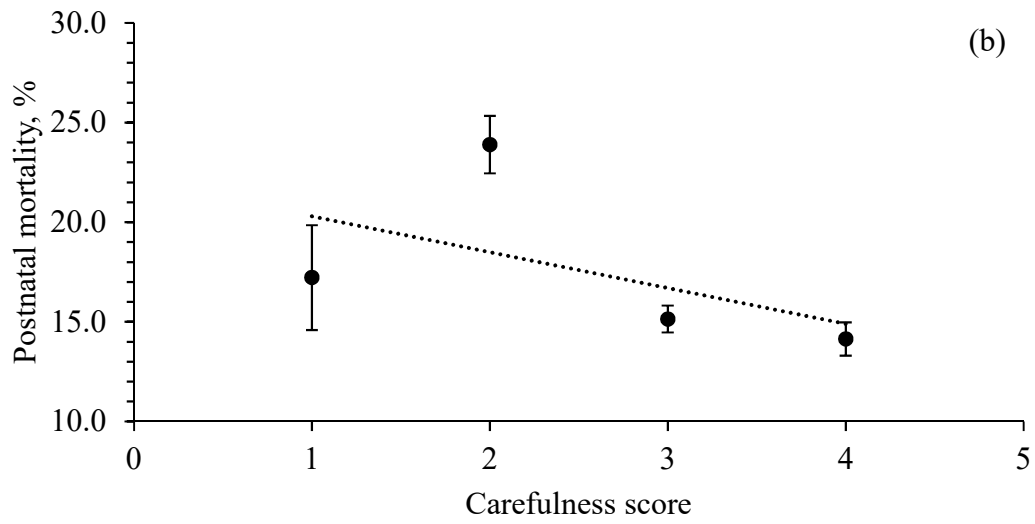
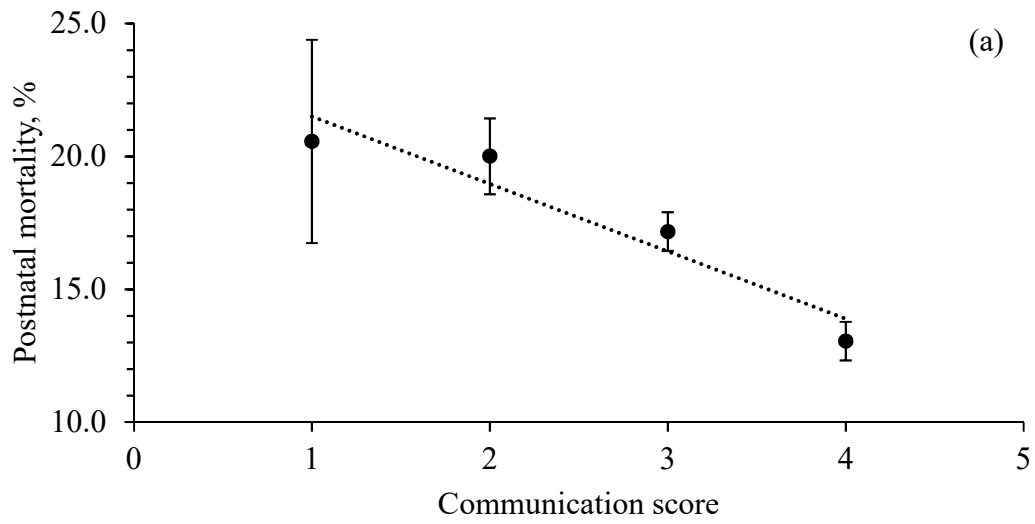


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497 Fig. 7: Relation between sow parity number and behavioural scores: (a) sow communication to piglets

498 ( $F_{1,805} = 14.3$ ;  $P < 0.001$ ); (b) sow carefulness to piglets ( $F_{1,805} = 15.7$ ;  $P < 0.001$ )

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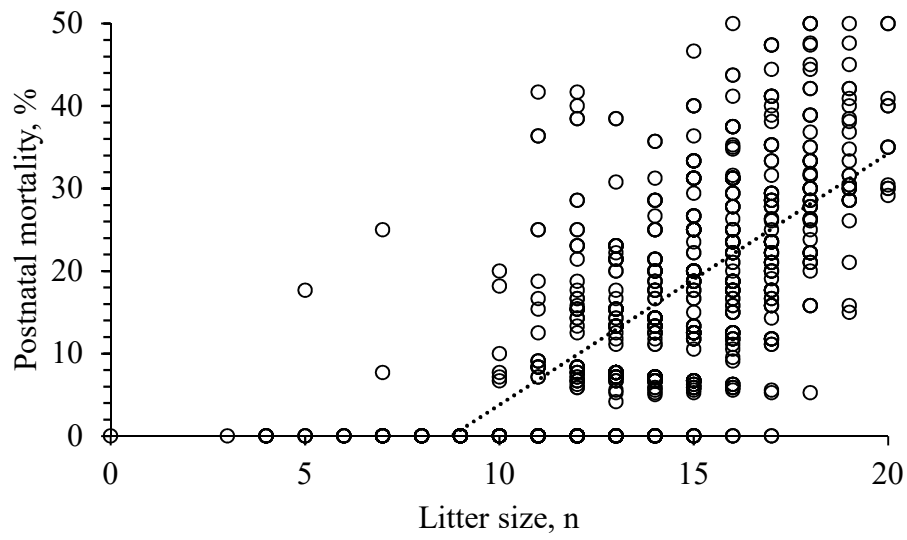
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501 Fig. 8: Relation between postnatal mortality and behavioural scores: (a) sow communication to piglets

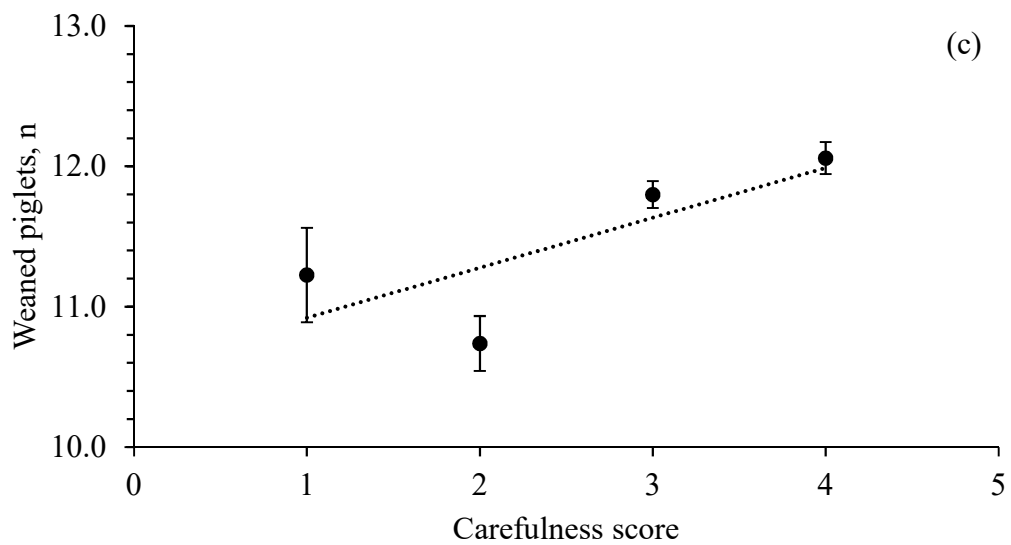
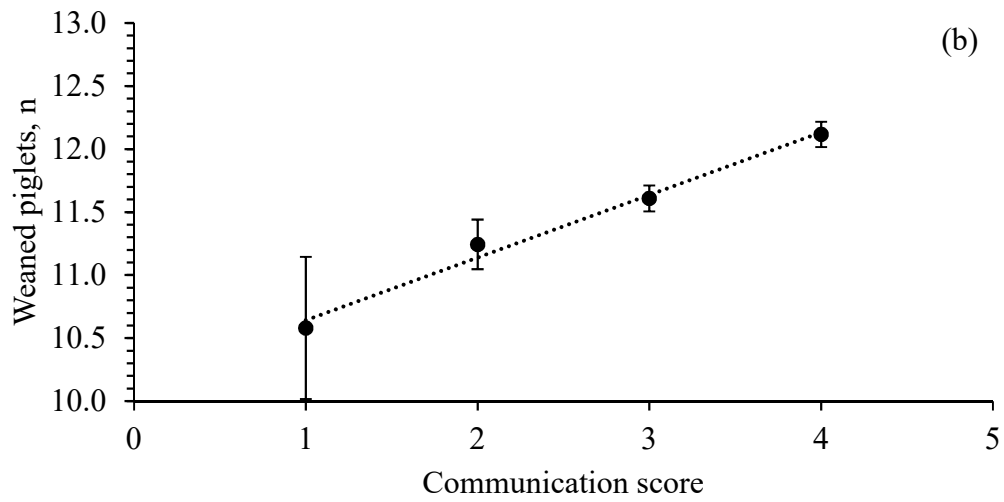
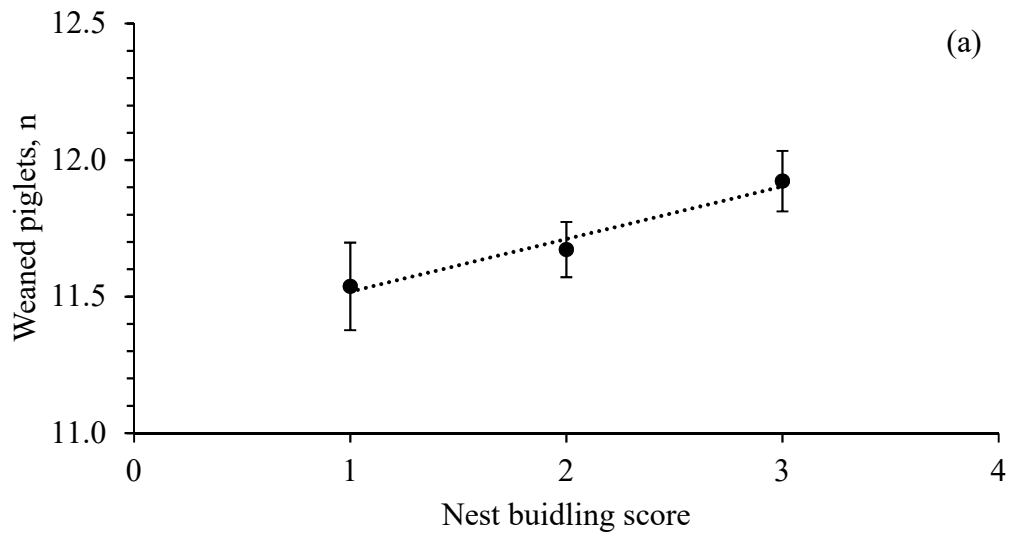
502 ( $F_{1, 799} = 13.7$ ;  $P < 0.001$ ); (b) sow carefulness to piglets ( $F_{1, 799} = 6.2$ ;  $P = 0.013$ )

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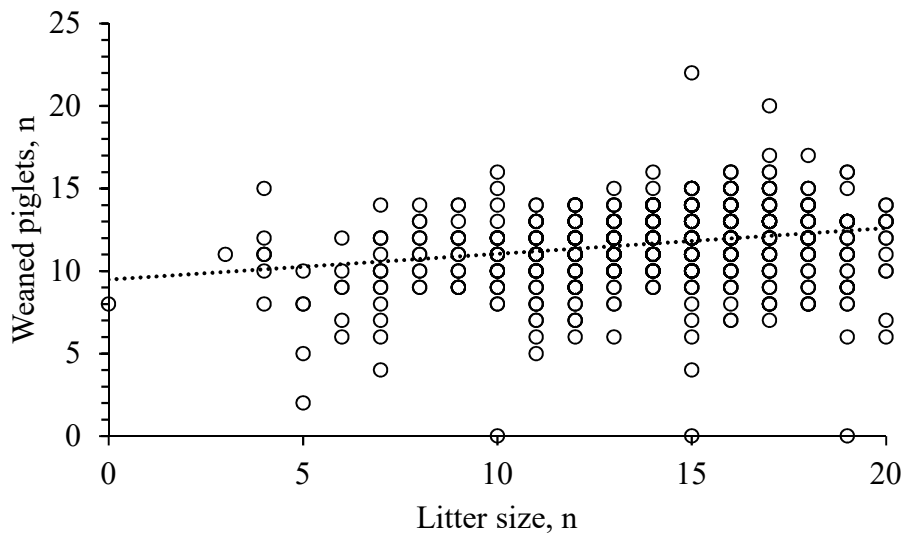




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 505 Fig. 9: Relation between litter size and postnatal mortality ( $F_{1, 799} = 695.1; P < 0.001$ )  
 506



507 Fig. 10: Relation between number of weaned piglets and behavioural scores: (a) nest building ( $F_{1, 799} =$   
 508 6.8;  $P = 0.009$ ); (b) sow communication to piglets ( $F_{1, 799} = 14.0$ ;  $P < 0.001$ ); (c) sow carefulness to  
 509 piglets ( $F_{1, 799} = 6.8$ ;  $P = 0.009$ )



510  
 511 Fig. 11: Relation between number of weaned piglets and litter size at birth ( $F_{1, 799} = 42.1; P < 0.001$ )  
 512