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Risk Factors for Prolonged Birth Interval in Modern Swine Farms in Vietnam

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ABSTRACT

The present study aimed to investigate factors influencing the prolonged birth interval in swine, defined as a birth interval longer than 30 minutes. In total, 3380 piglets born from 239 Landrace x Yorkshire sows from 5 farms in the North of Vietnam were included in this study. The dependent variable was the prolonged birth interval, and independent variables included parity, gestation length, litter size, relative birth order, crown-rump length, birth weight, body-mass index, ponderal index, piglet's gender, dead-born piglet, and oxytocin use. Important factors for the prolonged birth interval were determined by using Generalized Linear Mixed Models. The incidence of the prolonged birth interval was 14.5%. Crown-rump length (OR=1.09, 95% CI=1.06-1.14), birth weight (OR=1.06, 95% CI=1.02-1.09), and dead-born piglet (OR=1.98-2.08, 95% CI=1.38-2.97) were positively associated with the prolonged birth interval, while litter size (OR=0.90, 95% CI=0.96-0.94) negatively correlated with the prolonged birth interval. The incidence of prolonged birth interval decreased with an increase in relative birth order, bottoming at relative birth order of 40-80, and then increased to the end of parturition. The last piglets had the highest risk of experiencing prolonged birth intervals. This study indicated that prolonged birth interval in swine was common; therefore, careful farrowing supervision should be practiced to reduce stress in sows and piglets.

Keywords: birth weight; crown-rump length; prolonged birth interval; relative birth order; swine

INTRODUCTION

Perinatal mortality causes substantial loss to modern pig farming, with the stillbirth rate up to 10% (Langendijk & Plush, 2019). Among risk factors for stillbirth, body conformation characteristics, farrowing duration, and birth interval are the most important (Baxter *et al.*, 2009; Nam & Sukon, 2020b). The farrowing duration ranging from 130-396 minutes (van Rens & van der Lende, 2004; van Dijk *et al.*, 2005; Oliviero *et al.*, 2010; Bjorkman *et al.*, 2017; Nam & Sukon, 2020c) is the cumulation of different birth intervals. Long farrowing duration increases stillbirth rates and reduces the survival and growth rate of suckling piglets (Herpin *et al.*, 1996; Rootwelt *et al.*, 2013). Reductions of farrowing duration and birth interval were thought to reduce stillbirth. However, when these two factors were shortened by using oxytocin at the early stage of expulsion, the incidence of stillbirth increased (Mota-Rojas *et al.*, 2005). Those results suggest that the effects of farrowing duration and birth interval on stillbirth are complicated and are in conjunction with the other factors.

Piglet birth interval varies between 15-20 minutes (van Rens & van der Lender, 2004; Van Dijk *et al.*, 2005; Motsi *et al.*, 2006; Vallet *et al.*, 2010; Nam & Sukon, 2020b). Factors associated with birth interval include litter size (Plush *et al.*, 2018), birth order (Vallet *et al.*, 2010), gestation length (Mota-Rojas *et al.*, 2014), birth weight, and the thickness of the placenta (van Rens & van der Lender, 2004; van Dijk *et al.*, 2005; Canario *et al.*, 2006). In the practice of farrowing supervision, assisted farrowing was commonly used by either oxytocin injection or manual extraction to help piglets and sows when the birth interval was prolonged. However, the prolonged birth interval definition may vary among studies; therefore, the information about risk factors for the prolonged birth interval is inadequate.

The present study aimed to evaluate the effect of different factors including parity, gestation length, litter size, birth order, birth weight, crown-rump length, body mass index, ponderal index, and the use of oxytocin on the prolonged birth interval, which was defined as a birth interval longer than 30 minutes (Cozler *et al.*, 2002).

MATERIALS AND METHODS

Ethical Approval

This study was carried out with the approval of the animal ethics committees of the Vietnam National University of Agriculture (Approval number: VNUA-2020/06).

Animals and Housing

This study was conducted from May 2020 to January 2021 on 5 farms in the North of Vietnam. In total, 3380 piglets born from 239 Landrace x Yorkshire sows were enrolled in this study. Sows in estrus were artificially inseminated twice with Duroc boars' semen. Pregnant sows were housed in individual crates sized about 220 cm x 60 cm (length x width). During pregnancy, sows were daily fed 2.0-3.5 kg of industrialized feed containing 13%-17% crude protein and metabolizable energy of 2900-3100 kcal/kg. Sows received water *ad libitum* through a bitten nipple drinking system. Sows were bathed once or twice daily, depending on the ambient temperature. Vaccinations against classical swine fever, foot and mouth diseases, porcine circovirus, porcine respiratory and reproductive syndrome, and Aujeszky's disease were conducted on all experimental sows. Pregnant sows were removed to farrowing crates about 5-7 days before the estimated farrowing date. Pregnant and farrowing crates were cleaned twice every day.

Data Collection and Definition

During parturition, data in parity number, gestation length, litter size, birth interval, piglets' gender, crown-rump length, birth weight, oxytocin injection, dead-born, and live-born piglets were recorded. Gestation length was the interval from insemination to parturition. Litter size included born alive and born dead piglets. The birth interval was the interval between the births of two successive piglets; therefore, the firstborn piglets did not have a birth interval. Relative birth order (RBO) was calculated by using the following equation: relative birth order = 100* birth order/litter size (Motsi *et al.,* 2006). Birth weight was measured by a digital scale with an error of 5 g. The crown-rump length was measured by a tape measure with an error of 1 mm from the top of piglets' heads to the bottom of their buttocks. Body-mass index and ponderal index were calculated by the following equations: body mass index =birth weight (kg)/(crown-rump length (m))^2, ponderal index= birth weight (kg)/(crown-rump length (m))^3. The measurements of birth weight and crown-rump length were done immediately after piglet drying and took about 35-40 s in a humane way to avoid any stress in animals. An injection of oxytocin (20UI) might be applied if a birth interval exceeded 30 minutes and no piglet was obstructed in the vagina, which was ensured by a manual examination. Each sow received at most one dose of oxytocin. The birth order at which oxytocin injection occurred was recorded. During farrowing, sows were fully supervised by at least one veterinarian, and all data were recorded through human observation. Newborn piglets were dried with hygroscopic flour and fed colostrum, then put into incubators which were heated with infrared lamps.

Statistical Analysis

All available data were used for descriptive statistics (Table 1). A birth interval longer than 30 minutes was considered a prolonged birth interval. This categorization was based on a report by Cozler *et al.* (2002). Firstborn piglets that did not have a birth interval were discarded; therefore, risk analysis consisted of 3141 piglets. Generalized Linear Mixed Models (GLMMs) were used to investigate the risk factors for the prolonged birth interval to deal with hierarchical data where piglets were born from the same sows. Sows nested in the farms were fitted as random factors to take into account for potential difference among litters and potential variation among farms, other factors including parity, gestation length, litter size, piglet's gender, dead born piglet, birth order, birth weight, crown-rump length, body mass index, ponderal index, and oxytocin use were fitted as fixed factors. Since the oxytocin was used at various birth orders, the effect of this drug on the incidence of the prolonged birth interval was investigated in only piglets born from litters that needed oxytocin injection (1807 piglets). In contrast, piglets born from litters that need no oxytocin injection were excluded. Continuous variables that had a curvilinear association with the prolonged birth interval (assessed by logistic

Table 1. Descriptive statistics of 3141 piglets and 239 sows

Variables	n	Mean±SD/percentage
Parity	239	4.6±2.5
Gestation length (day)	239	115.5±1.7
Litter size	239	14.1±3.0
Farrowing duration (minute)	239	231.7±117.3
Crown-rump length (cm)	3380	27.5±3.1
Birth weight (g)	3380	1356±355
Body mass index	3380	17.9±4.4
Ponderal index	3380	66.6±22.5
Dead-born rate (%)	3380	7.2 (244/3380)
Average birth interval (minute)	3141	18.2±28.5
Normal birth interval (minute)	2687	10.7±8.1
Prolonged birth interval (minute)	454	62.6±54.2
Incidence of prolonged birth interval at piglet level (%)	3141	14.5 (454/3141)
Incidence of prolonged birth interval at litter level (%)	239	77.0 (184/239)

Note: SD: Standard deviation.

regression in SPSS, IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY: IBM Corp) were partitioned into categorical variables to examine their effects at different ranges on the outcome. Initially, univariate GLMMs were run to determine the most significant factor (based on Akaike's Information Criterion (AIC) and p-value of the model) for the prolonged birth interval. All factors significant at a P-value <0.1 were retained for multivariate GLMMs. The most significant variable was then coupled with the other significant factors to be analyzed in different GLMMs. Further addition of factors was based on AIC and marginal R^2 and conditional R^2 until the model best explaining variation of the prolonged birth interval was built (Table 3). All tests were conducted in RStudio Desktop 1.3.1093 (Boston, MA, RStudio Team: Integrated Development for R), and a p<0.05 was considered significant.

RESULTS

Descriptive statistics are presented in Table 1. The average birth interval was 18.2±28.5 minutes, the incidence of prolonged birth interval at piglet level was 14.5%, and that at litter level was 77.0%. The incidence of the prolonged birth interval was 24.2% and 13.6% in dead-born and live-born piglets, respectively. Those incidences in male and female piglets were 16.0% and 12.8%, respectively. About 12.4% of piglets born before the oxytocin injection experienced the prolonged birth interval, and 13.3% of piglets born after oxytocin injection had the same condition. The lowest incidence of the prolonged birth interval was at RBO of 40-80 (10.8%, birth interval =15.2 minutes) and that of RBO of 95-100 was the highest (29.2%, birth interval =28.8 minutes). At the other RBO, the incidence of prolonged birth interval ranged between 14.4% (RBO=80-95) and 15.8% (RBO≤40).

Univariate GLMMs showed that gestation length, litter size, crown-rump length, relative birth order, birth weight, body-mass index, ponderal index, piglets' gender, and dead-born piglet were associated with the prolonged birth interval. By contrast, parity and use of oxytocin did not have any significant effect on the prolonged birth interval (Table 2). Marginal R^2 showed that every single independent variable explained less than 3.1% variation of the prolonged birth interval incidence, with RBO, litter size, and crown-rump length being the most explanatory factors (2.4-3.1%).

Model 1, the best model, explained variation of prolonged birth interval in swine (mR^2=0.086, cR^2=0.174) selected RBO, crown-rump length, litter size, and dead-born piglets as the most significant risk factors (Table 3). When crown-rump length was replaced by birth weight Model 2 had an mR^2 of 0.075, and a cR^2 of 0.170 (Table 3). When gender was included, both models were still significant; however, their mR^2 and cR^2 did not increase. Body mass index and ponderal index were not selected because they were highly correlated with and less explanatory than crown-rump length and birth weight. Consequently, depending on models, fixed factors could explain from 7.5%-8.6% variation of incidence of the prolonged birth interval, and the whole models could explain the variation of incidence of the prolonged birth interval as much as 17.0%-17.4%. Crown-rump length, birth weight, and dead-born piglet positively correlated with the prolonged birth interval, whereas litter size was negatively associated with the prolonged birth interval (Table 3). The incidence of prolonged birth interval decreased to RBO of 40-80 and increased to RBO of 95-100.

DISCUSSION

Increased birth interval has been widely known as a risk factor for stillbirth in piglets (Van Dijk *et al.,* 2005;

Table 2. Univariate Generalized Linear Mixed Models analysis for potential risk factors for prolonged birth interval (n= 3141 piglets, oxytocin use analysis included 1807 piglets)

Covariate	OR, 95%CI; P	mR^2 and cR^2
Parity	1.03; 0.98-1.09; 0.280	0.001; 0.120
Gestation length (day)	1.03; 1.03-1.03; <0.001	<0.001; 0.121
Litter size	0.90; 0.86-0.94;<0.001	0.024; 0.121
Crown-rump length (cm)	1.11; 1.10-1.11; <0.001	0.028; 0.137
Birth weight (100g)	1.06; 1.06-1.06; <0.001	0.013; 0.133
Body mass index	0.98; 0.98-0.99; <0.001	0.001; 0.117
Ponderal index	0.99; 0.99-0.99; <0.001	0.009; 0.122
Live-born piglet	1	0.009; 0.124
Dead-born piglet	2.02; 1.43-2.85<0.001	0.009; 0.124
Female	1	0.005; 0.125
Male	1.31; 1.06-1.61; 0.0125	0.005; 0.125
RBO=40-80	1	0.031; 0.152
RBO=80-95	1.43; 1.06-1.95; 0.020	0.031; 0.152
RBO <=40	1.59; 1.28-2.05; <0.001	0.031; 0.152
RBO =96-100	3.65; 2.59-5.14; <0.001	0.031; 0.152
Born before the use of oxytocin	1	<0.0001; 0.176
Born after the use of oxytocin	1.03; 0.75-1.42; 0.844	<0.0001; 0.176

Note: OR: odds ratio; CI: confidence interval; P: probability value; mR^2: marginal R-squared.

Table 3. Multivariate Generalized Linear Mixed Model analysis for potential risk factors for prolonged birth interval (n= 3141 piglets)

Covariate	Model 1 (OR, 95%CI; P)	Model 2 (OR, 95%CI; P)
RBO=40-80	1	1
RBO=80-95	1.37; 1.00-1.87; 0.047	1.39; 1.02-1.89; 0.037
RBO <=40	1.64; 1.28-2.11;<0.001	1.64; 1.28-2.11; <0.001
RBO =96-100	3.25; 2.31-4.57; <0.001	3.33; 2.36-4.71; <0.001
Litter size	0.90; 0.86-0.94; <0.001	0.90; 0.86-0.94; <0.001
Live-born piglet	1	1
Dead-born piglet	1.98; 1.38-2.82; <0.001	2.08; 1.45-2.97; <0.001
Crown-rump length (cm)	1.09; 1.06-1.14; <0.001	NI
Birth weight (100g)	NI	1.06; 1.02-1.09; <0.001

Note: OR: odds ratio; CI: confidence interval; P: probability value, NI: Not included. Marginal R^2 and conditional R^2 of model 1 and model 2 were 8.6% and 17.4%, and 7.5% and 17.0%, respectively. In the model 1, the marginal R^2 was 3.1%, 5.7%, 7.7%, and 8.6% when RBO, CRL, LS, and dead-born piglets were respectively added to the model. In the model 2, the marginal R^2 was 3.1%, 4.1%, 6.4%, and 7.5% when RBO, BW, LS, and dead-born piglets were respectively added to the model. Examples of OR explanation: When the crown-rump length of piglets increased by 1 cm, their likelihood of being born with a prolonged birth interval increases 1.09 times. Similarly, when the birth weight of piglets increased by 100 g, their likelihood of being born with a prolonged birth interval increase 1.06 times.

Pedersen *et al.*, 2006; Vallet *et al.*, 2010; Langendijk *et al.*, 2018; Nam & Sukon, 2020b), which causes substantial economic loss to pig husbandry. Categorizing a continuous birth interval into a binary prolonged birth interval helps farmers be aware of the time point at which farrowing should be carefully supervised, or farrowing assistance may be needed. The present study indicates that crown-rump length, birth weight, dead-born piglet, litter size, and the relative birth order are important factors affecting the prolonged birth interval in swine. Surprisingly, this is the first study to evaluate the effect of crown-rump length, body-mass index, and ponderal index on birth interval/prolonged birth interval. Interestingly, among body conformation characteristics, crown-rump length is the most important factor explaining the prolonged birth interval variation.

Several studies have reported the positive effect of birth weight on the birth interval (van Dijk *et al.*, 2005; Canario *et al.*, 2006), while others did not find a similar effect (Motsi *et al.*, 2006). Van Rens & van der Lende (2004) argued that the thickness of fetal membrane rather than birth weight was responsible for the birth interval; bigger piglets have a thicker fetal membrane and have to spend more time breaking its membrane resulting in a longer birth interval. This study found that crown-rump length, compared with birth weight, was more significant concerning the prolonged birth interval. The positive association between crown-rump length and the prolonged birth interval was partly explained via the direct proportion between crown-rump length and birth weight (Spearman's rho =0.595, p<0.001). Furthermore, the increased crown-rump length may slow down the movement of piglets in reproductive canals due to the elevated friction, particularly due to an increase in the risk of being blocked in reproductive canals. It can be highlighted that birth weight, body mass index, and ponderal index are some of the most significant factors that influence stillbirth (Baxter *et al.*, 2008; Baxter *et al.*, 2009; Nam & Sukon, 2020b). However, regarding birth interval/prolonged birth interval, crown-rump length is a more explanatory factor.

Similar to results reported by previous studies that found a negative association between litter size and birth interval (Canario *et al.*, 2003; Canario *et al.*, 2006; Pedersen *et al.*, 2006; Plush *et al.*, 2018), in the present study, large litter size reduced the incidence of prolonged birth interval. This association may be the result of the negative correlation between litter size and crown-rump length (Spearman's rho = -0.091, p<0.001) and birth weight in this study (Spearman's rho = -0.149, p<0.001) and in another study (Nam & Sukon, 2020a).

The nonsignificant effect of parity on the incidence of prolonged birth interval in this study agrees with the result reported in previous documents (van Dijk *et al.*, 2005; Motsi *et al.*, 2006; Yang & Jeon, 2019). It is expected that the incidence of prolonged birth interval elevates in high parity sows due to the decreased uterine contraction in these animals (Motsi *et al.*, 2006). The finding can be partly explained via the negative correlation between parity and birth weight found in this study (Spearman's rho =-0.015; p=0.04).

Gestation length has been found to negatively influence the birth interval with the explanation that piglets are more mature, and the preparation for farrowing is more effective in gestation length >114 days compared to that in gestation length <115 days (Mota-Rojas *et al.*, 2014). However, in this study, gestation length is positively related to crown-rump length, and this relationship may eliminate the beneficial effect of piglet maturity and the well-prepared parturition in longer gestation resulting in a positive association between gestation length and prolonged birth interval.

Many researchers found a positive association between stillbirth and birth interval (van Dijk *et al.*, 2005; Pedersen *et al.*, 2006; Vallet *et al.*, 2010; Langendijk *et al.*, 2018; Nam & Sukon, 2020b). In contrast, Canario *et al.* (2003) reported a negative association between stillbirth and birth interval. However, that study calculated average birth interval equal to farrowing duration dividing by litter size, and that calculation may narrow down the variation of the birth interval, potentially resulting in such finding. The relationship between stillbirth and birth interval may be mutual; stillborn piglets cannot actively move through the reproductive canal (Taverne

& van der Weijden, 2008) thereby lengthening the birth interval, whereas long birth interval predisposes piglets to more stress and asphyxia, leading them to stillbirth.

In comparison with female piglets, male piglets in this study were bigger (1380 g *vs* 1330 g) and longer (27.8 cm *vs* 27.3 cm), which may explain an increased prolonged birth interval in the latter group.

Birth order has been substantiated as an important factor that affects birth interval in several previous studies (van Rens & van der Lender, 2004; van Dijk *et al.,* 2005; Motsi *et al.,* 2006; Vallet *et al.,* 2010). van Rens & van der Lender (2004) observed an increase in the birth interval when birth order went beyond 10. Similar to the finding by Motsi *et al.* (2006), who reported that birth interval decreased with the increase in birth order up to RBO of 40, the present study found that the incidence of prolonged birth interval decreased to RBO of 40 and stabilized to RBO of 80. Our finding also corroborates the results reported by Vallet *et al.* (2010) and Motsi *et al.* (2006) that the last piglets had longer birth intervals, and van Dijk *et al.* (2005) and Motsi *et al.* (2006) that piglets in middle-rank had the shortest birth interval. The lowest incidence of prolonged birth interval in middle-rank could be due to the increase in oxytocin release at the first hour of parturition (Lawrence *et al.,* 1995), and the increased incidence of prolonged birth interval in the late stage of the fetal expulsion process could be due to uterine fatigue (Mota-Rojas *et al.,* 2007) and the long-distance from the end of the uterine horns to the outside that these fetuses had to travel (Motsi *et al.,* 2006). The uterine fatigue hypothesis is corroborated by the finding in this study that the incidence of prolonged birth interval did not change after exogenous oxytocin injection (12.4% *vs* 13.3%). However, these potential mechanisms cannot completely explain the sharply increased incidence in the last piglets. One can hypothesize that the stimulation of one piglet left in the uterus may not efficiently trigger the uterine contraction and/or fetal membrane breaking and/or the cervical opening to push the piglet through the reproductive tract.

CONCLUSION

These data indicated that prolonged birth interval was common in swine. Increased crown-rump length and birth weight, dead-born piglet, small litter size, and low and high relative birth order were associated with the increased prolonged birth interval. Since the birth interval is a risk factor for stillbirth, and farrowing is a painful condition, supervision of farrowing and assisting sows and piglets with prolonged birth intervals will reduce prenatal mortality in piglets and stress in sows.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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