Mortality, death interval, survivals, and herd factors for death in gilts and sows in commercial breeding herds

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ABSTRACT: The objectives of this study were to measure death intervals and survival, to determine mortality rate and mortality risks, and to investigate the association of herd factors with mortality risk in individual female pigs. This study was conducted by obtaining female data with lifetime records of 65,621 females born between 1999 and 2002, and herd data with mean measurements of 5 yr from 2000 to 2004 in 105 herds. Annualized mortality rate was calculated as the number of dead females divided by the sum of life days in all gilts and sows, multiplied by 365 d. Mortality risk was calculated as the number of dead females divided by the number of surviving females at farrowing in each parity. Death interval in gilts was defined as the number of days from birth to death, and that in sows was the number of days from the last farrowing to death. A Cox proportional hazards model was used to obtain the survival probability by parity. Logistic regression analyses were used to investigate the association of herd factors with mortality risk in individual females in each parity. Of the 65,621 females, the mortality risk was 9.9%, and the annualized mortality rate was 3.9%. Of the 6,501 dead females, death intervals in gilts and sows were 294.7 and 55.0 d, respectively. In gilts, survival probability rapidly decreased at 33 and 50 wk of age, around the first mating and the first parturition. In contrast, survival probability in sows decreased at wk 1 after farrowing, and rapidly decreased at wk 20 and 21 after farrowing in all parity groups that were around a subsequent peripartum period. The percentages of death on wk 0, 1, and 2 after the last farrowing in all the dead sows were 6.5, 23.5, and 10.1%, respectively. Approximately 10% of deaths also occurred from wk 20 to 21 after the last farrowing. Death interval in parity ≥5 was the shortest among all parity groups (49.2 d; *P* < 0.05). Mortality risks in parities 0 and 1 were 1.44 and 1.83%, respectively. As parity increased from 2 to ≥5, mortality risk increased from 1.63 to 5.90%. Herd factors (greater herd mortality, less herd productivity, and smaller herd size) were associated with greater mortality risk in individual females in parity 0 to ≥5, parity 4 and ≥5, and parity 1 to 4, respectively (*P* < 0.05). In conclusion, females in peripartum periods, gilts, and high-parity sows are at a greater risk of dying. Increased care should be implemented for prefarrowing females and early-lactating sows.

Key words: death, management, mortality, sow, survival, well-being

INTRODUCTION

Reduced mortality is an indicator of maternal health (Geller et al., 2006) and animal well-being, and prevents economic loss in commercial herds (Deen and Xue, 1999). Pregnancy and parturition may be major risks for mortality in female animals (Chagnon et al., 1991; Thomsen et al., 2004). Approximately 84% of female pigs in commercial herds are pregnant or lactating (Koketsu, 2005), and may be at a greater risk of dying. Mortality risks in US herds from 1998 to 2006 increased from 5.9 to 8.8% (PigCHAMP DataSHARE, 2006). The percentage of dead females among all the removed females was 8.2% in US herds (Anil et al., 2005) and 4.3% in Swedish herds (Engblom et al., 2007). Few previous studies have estimated the risk associated with the life of individual females by using populations at risk and a measure of time (pig days) as a denominator for risk measurement (Friis and Sellers, 1996).

The mean death interval from farrowing was 72 d, whereas approximately 20 and 40% of deaths occurred in wk 1 and in wk 11 or later after farrowing, respec-
tively (Stein et al., 1990b). Patterns of death intervals and survival of females in each parity have not been described well; in particular, those in gilts have not been reported.

Herd measurements indicate the relative efficiency of herd operations, production systems (King et al., 1998), and herd health. Herd measurements such as herd size, productivity, and mortality may be related to the mortality risk in individual females. For example, high herd mortality, indicating poor hygiene or a chronic disease in the herd, may increase the mortality risk in individual females. No research has yet quantified an association between herd measurements and mortality risk in individual females within a herd having a hierarchical structure.

The objectives of this study were to measure death intervals and survival, to determine mortality rate and mortality risks, and to investigate the herd factors associated with mortality risk in individual females in commercial breeding herds.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the data were obtained from our DataSHARE program, and we did not perform an experiment with live animals.

Data and Selection Criteria

Approximately 140 herds in Japan using a recording software (PigCHAMP) were requested to mail their data files to Meiji University when they renewed the yearly maintenance contract. By August 31, 2006, data files were received from 122 herds. Of these 122 herds, 17 herds were not used because the birth dates of sows were not recorded or were inaccurate. Mean herd measurements in the 5-yr duration from 2000 to 2004 were collected for 105 herds. Mean (±SEM) and median herd size were 320 ± 38.5 and 225 females, respectively, with a range between 22 and 3,063 females. Average herd size from 2000 to 2004 increased from 296 to 341 females. Herd productivity was measured as pigs weaned-mated females⁻¹yr⁻¹ (PWMFY). Mean (±SEM) and median PWMFY were 21.3 ± 0.22 and 21.6 pigs, respectively. Mean (±SEM) and median herd mortality were 5.1 ± 0.23 and 4.9%, respectively. The data included approximately 1.4% of all herds, with approximately 4% of female inventories in Japan. The country had 7,770 breeding herds and 917,500 gilts and sows in February 2004 (Ministry of Agriculture, Forestry and Fisheries of Japan, 2007). Females in the study herds were mainly F1 crossbreds between Large White and Landrace, which were reproduced within the herd or were purchased from international breeding companies. These breeding stocks were originally imported from the United States or Europe. The lactation and gestation diets of each herd were formulated by using imported corn and soybean meal.

Lifetime records of females born from 1999 to 2002 were extracted from the data files of 105 herds. Records of 65,621 females in the 105 herds were used for this study. Of the 65,621 females, 2,620 (4.0%) were still alive when the data were collected. In addition, 22 females having no record of farrowing date were omitted when death intervals were analyzed.

Definitions and Categories of Measurements

Females included both gilts and sows: a gilt was defined as a female entered into a herd but that had not farrowed, and a sow was a female that had farrowed at least once. Removed females were divided into 2 groups, as dead and culled. Culled animals included culled, euthanized, transferred, and type-unrecorded females (88.3, 0.4, 0.6, and 0.4%, respectively).

The death interval in gilts was defined as the number of days from birth to death, and the death interval in sows was the number of days from the last farrowing to death. Culling interval in gilts was the number of days from birth to culling, and culling interval in sows was the number of days from the last farrowing to culling. Mortality risk was calculated as the number of dead females divided by the number of surviving females at farrowing in each parity. Annualized mortality rate or culling rate were calculated as the number of dead females or the number of culled females divided by the sum of the female life days after the birth date to the removal date of all gilts and sows, multiplied by 365 d. Female life days was defined as the number of total days from the birth date to the removal date. In surviving females, female life days was defined as the number of total days from the birth date to the collection date.

Death at d 0 of farrowing was determined when a sow had at least 1 pig born. Death before farrowing was recorded when a female had no pigs born. Week 0 after farrowing was defined as d 0 of farrowing, wk 1 was from d 1 to 7 after farrowing, wk 2 was from d 8 to 14 after farrowing, and so forth. Frequency distributions (%) of deaths in the number of weeks from birth or the last farrowing to death were obtained as a death pattern in gilts and in sows. A peripartum period was defined as wk 0 and 1 and wk 20 and 21, which indicate the periods after farrowing and before farrowing.

Herd mortality was calculated as the number of dead females divided by the average female inventory during the 5-yr period, multiplied by 100. The average female inventory (herd size) was calculated as the total female life days during the 5-yr period divided by 365 d × 5 yr. Herd mortality was used as an indicator of the herd health status, whereas mortality risk in individual females was a risk measurement for gilts and sows when using populations at risk. Average culling rate was not used as a herd factor in this study because average culling rate is not a critical measurement for herd mortality and productivity (Stein et al., 1990a;
D’Allaire and Drolet, 1999) and is not associated with herd mortality risk (Koketsu, 2000).

Reasons for death were recorded by producers, and necropsies were not commonly done. The reasons of death were grouped into 5 categories: unknown, peripartum problems, prolapses, locomotor problems, and other diseases.

**Statistical Analysis**

All statistical analyses were performed in SAS (SAS Inst. Inc., Cary, NC). A chi-square test was used to compare the frequency distribution (%) of death intervals among parity groups. A linear mixed-effects model using the MIXED procedure was applied to compare removal measurements between dead females and culled females, and to compare death intervals between parity groups by using a Tukey-Kramer multiple comparisons test. Herd was included as a random effect. A square root transformation was performed on death intervals or culling intervals to use as a dependent variable. After the analysis, the results were back-transformed.

A multilevel model was used to take the hierarchical structure of the individual females within the herd into account (Singer, 1998). Two-level logistic regression analyses using the GLIMMIX procedure were used to examine the relationship between the mortality risk in individual females and herd factors in each parity. The herd was level 2, and an individual female was level 1 (Singer, 1998). The dependent variable was whether a female died in each parity. Independent variables were 3 continuous variables of herd factors: herd mortality, PWMFY, and herd size. In these 2-level analyses, herd was included as a random intercept to adjust for the variance component representing the effect of herd, and the denominator degree of freedom = Between-Within option was used (Singer, 1998).

A Cox proportional hazards model with PHREG procedure was used to obtain the survival probability after birth in gilts and after farrowing in sows. Survival probabilities indicate estimates of the survivor function, controlling for the effects of covariates (Allison, 1995). Dead females were treated as uncensored subjects, whereas surviving females and culled females in each parity were treated as censored subjects. Sows were stratified according to parity (parity 1, 2, 3, 4, and 5 or greater) because previous studies have recommended modeling the baseline hazard function within a parity, not over the entire life of the animals (Röxström et al., 2003; Ducrocq, 2005). Censored times in gilts and in sows were 70 wk of age and wk 30 after farrowing, respectively. Herds were included in the model as a covariate.

**RESULTS**

Of the 65,621 females, mortality risk was 9.9%, and the risks by birth year from 1999 to 2002 ranged from 8.9 to 10.6%. Annualized mortality rate and culling rate were 3.9 and 33.8%, respectively. Death intervals in gilts and sows were shorter than culling intervals ($P < 0.05$; Table 1). Mean parity at removal in dead females was 3.2, and dead females had lesser parities at removal than did culled females ($P < 0.05$). In 6,501 dead females, the percentages of reasons for death in unknown, peripartum problems, prolapses, locomotor problems, and other diseases were 51.6, 18.3, 10.8, 4.2, and 15.1%, respectively.

Figures 1 and 2 show survival curves in gilts and sows, and frequency distributions (%) of the number of weeks from birth to death in gilts and the number of weeks from the last farrowing to death in sows. In gilts, survival probability decreased continuously from 24 to 56 wk of age. In the dead gilts, 3.9 and 3.7% of deaths occurred at 33 and 50 wk of age, respectively.

In contrast to gilts, survival probability in sows decreased at the first week after farrowing and decreased rapidly at wk 20 and 21 after farrowing in all parity groups. Of all the dead sows, the percentages of death on wk 0, 1, and 2 after the last farrowing were 6.5, 23.5, and 10.1%, respectively, and the percentages in wk 20 and 21 after the last farrowing were 5.7 and 4.9%, respectively. In addition, the frequency distributions of death intervals differed among parity groups ($P < 0.05$). The percentages of deaths from farrowing to wk 1 after the last farrowing in parities 1 and $\geq$5 were 31.5 and 33.2%, respectively, whereas the percentages in parities 2 and 3 were 21.0 and 27.8%.

Death intervals in sows by parity ranged from 49.2 to 64.0 d (Table 2). The death interval in parity $\geq$5 was the shortest among all parity groups ($P < 0.05$), and

<table>
<thead>
<tr>
<th>Table 1. Comparison of removal measurements between dead and culled females</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurement</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td><strong>n</strong></td>
</tr>
<tr>
<td>Death or culling interval$^1$</td>
</tr>
<tr>
<td>Birth-to-death or culling interval in gilts, d</td>
</tr>
<tr>
<td>Farrowing-to-death or culling interval in sows, d</td>
</tr>
<tr>
<td>Parity at removal</td>
</tr>
</tbody>
</table>

$^a,b$Values within a row without a common superscript were different ($P < 0.05$).

$^1$Records of death or culling interval were missing in 22 sows.
that in parity 2 was longer than in parities 1, 4, and ≥5 ($P < 0.05$). Mortality risks in parities 0 and 1 were 1.44 and 1.83%, respectively (Table 2). As parity increased from 2 to ≥5, mortality risks increased from 1.63 to 5.90%.

Greater herd mortality was associated with greater mortality risks in individual females in all parity groups ($P < 0.05$; Table 3). In all parity groups, for each 1% increase in herd mortality, the mortality risk in individual females in the herd increased by 1.0031 to 1.0083 times ($P < 0.05$). In parity 1 to 4, the female risk decreased as each 100 females increased in herd size ($P < 0.05$). In parities 4 and ≥5, the female risk decreased as each 1 pig increased in PWMFY ($P < 0.05$).

Figure 1. Survival curve in gilts (line graph), and frequency distributions (%) of the number of weeks from birth to death in dead gilts (bar graph).

Figure 2. Survival curves in sows by parity (line graph), and frequency distributions (%) of the number of weeks from the last farrowing to death in dead sows (bar graph).
DISCUSSION

Results of this study revealed that females in the peripartum period are at a high risk of dying in any parity. The survival probability decreased rapidly, and approximately 40% deaths occurred in the peripartum period in each parity, especially before the end of pregnancy or within a week after farrowing. These results are consistent with previous studies showing that approximately one-half of all mortality occurs during the first 3 wk after the last farrowing (Deen and Xue, 1999) and that 42.1% deaths occurred in a peripartum period (Chagnon et al., 1991). Two possible reasons for deaths in this period are heart failure and uterine prolapse occurrences (Chagnon et al., 1991). Sows are recognized as having a small ratio of heart weight: BW of 0.3%, a low heart volume, and high myocardial sensitivity to oxygen deficiency (Lee et al., 1975; D’Allaire and Drolet, 1999). A prolapse occurrence is partially explained by their pelvic diaphragm, long and flaccid uterus, and dystocia (Smith, 1999). In addition, torsions of abdominal organs, uterine prolapse, and cystitis-pyelonephritis were mostly observed in high-parity sows (Chagnon et al., 1991; Christensen et al., 1995). High mortality in high-parity sows in our study may be related to these causes, although we did not perform necropsies. High mortality risks in high parities in this study were consistent with previous studies (Koketsu, 2000; Engblom et al., 2008). Furthermore, this study indicated that females in the peripartum period in a high parity were at greater risk of dying than those in a low parity.

In addition to high-parity sows, a greater death occurrence in early lactation in the frequency distribution, and a greater mortality risk in parity 1 than in parity 2 indicated that females in their first experiences of parturition were also at a high risk of dying. Two peaks in the death occurrences, and the decreased survival probability observed at approximately 33 and 50 wk of age in gilts indicated that gilts in the first mating and in the first prefarrowing period were at a high risk of dying. This finding is consistent with a previous study showing that gilts were at a high risk of

Table 2. Mortality risk and death interval by parity

<table>
<thead>
<tr>
<th>Parity</th>
<th>Surviving</th>
<th>Removed</th>
<th>Death</th>
<th>Mortality risk&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Death interval&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65,621</td>
<td>8,388</td>
<td>947</td>
<td>1.44</td>
<td>294.7 ± 2.89</td>
</tr>
<tr>
<td>1</td>
<td>57,233</td>
<td>7,512</td>
<td>1,046</td>
<td>1.83</td>
<td>54.2 ± 2.04&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>49,721</td>
<td>5,003</td>
<td>808</td>
<td>1.63</td>
<td>64.0 ± 2.24&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>44,718</td>
<td>4,988</td>
<td>810</td>
<td>1.81</td>
<td>59.2 ± 2.16&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>39,720</td>
<td>5,249</td>
<td>856</td>
<td>2.16</td>
<td>57.3 ± 2.08&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>≥5</td>
<td>34,471</td>
<td>31,851</td>
<td>2,034</td>
<td>5.90</td>
<td>49.2 ± 1.28&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total</td>
<td>65,621</td>
<td>63,001</td>
<td>6,501</td>
<td>9.91</td>
<td>—</td>
</tr>
</tbody>
</table>

<sup>a–c</sup>Values within a column without a common superscript were different (<i>P</i> < 0.05).

<sup>1</sup>Mortality risk was calculated as the number of dead females divided by the number of surviving females in each parity.

<sup>2</sup>Comparisons of death intervals between the parity groups were performed only in sows.

Table 3. Odds ratio of mortality risk in individual females<sup>1</sup> related to herd mortality, pigs weaned per mated female per year (PWMFY), and herd size in each parity<sup>2</sup>

<table>
<thead>
<tr>
<th>Parity group</th>
<th>n</th>
<th>Herd mortality</th>
<th>PWMFY</th>
<th>Herd size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65,621</td>
<td>1.0031*</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0023–1.0039)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>57,233</td>
<td>1.0039*</td>
<td>NS</td>
<td>0.9997*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0033–1.0046)</td>
<td></td>
<td>(0.9996–0.9998)</td>
</tr>
<tr>
<td>2</td>
<td>49,721</td>
<td>1.0033*</td>
<td>NS</td>
<td>0.9998*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0027–1.0040)</td>
<td></td>
<td>(0.9997–0.9999)</td>
</tr>
<tr>
<td>3</td>
<td>44,718</td>
<td>1.0036*</td>
<td>NS</td>
<td>0.9997**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0028–1.0043)</td>
<td></td>
<td>(0.9996–0.9999)</td>
</tr>
<tr>
<td>4</td>
<td>39,720</td>
<td>1.0031*</td>
<td>0.9990*</td>
<td>0.9998*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0030–1.0033)</td>
<td></td>
<td>(0.9982–0.9999)</td>
</tr>
<tr>
<td>≥5</td>
<td>34,471</td>
<td>1.0083*</td>
<td>0.9972*</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0062–1.0105)</td>
<td></td>
<td>(0.9951–0.9994)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Mortality risk in individual females was calculated as the number of dead females divided by the number of surviving females in each parity.

<sup>2</sup>The values in the parentheses were 95% confidence intervals.

<sup>3</sup>Units for herd factors: herd mortality, 1%; PWMFY, 1 pig; herd size, 100 females.

*<i>P</i> < 0.001; **<i>P</i> = 0.04; NS = not significant.
death (Deen and Xue, 1999). The behavioral and physiological changes that are related to the first experiences of estrus detection, mating, and parturition may increase their physical stress (von Borell et al., 2007). Additionally, pregnant gilts are still growing and their bodies have not yet matured (Rozeboom et al., 1996), and their small pelvis may be related to difficulty in farrowing (Baas, 2008).

Our study showed that the reduction in survival probability was greater at wk 20 and 21 after farrowing or prefarrowing than in early lactation, but the percentage of deaths in the frequency distribution was greater in early lactation than at a subsequent prefarrowing. This difference may be due to the larger population at risk in the first week after farrowing than at a subsequent farrowing.

Increased care of maternal health in the peripartum period in the farrowing barns (Yeske, 1999) would decrease the number of deaths of females and alleviate concerns for the well-being of females. Predicting the date of farrowing by using the records of previous gestation length would also be useful for producers to assist a sow’s farrowing (Sasaki and Koketsu, 2007).

The results of this study indicate that mortality risks of individual females in all parities increase to a certain degree as herd mortality increases. For example, herds having a high herd mortality might have some diseases, such as porcine reproductive and respiratory syndrome, that have spread worldwide to other pig herds, thereby increasing the occurrence of death by acute viremia (Benfield et al., 1999).

The results of this study, showing increased mortality risk in smaller herds, are not consistent with a previous study showing an increased mortality in larger herds in the United States (Koketsu, 2000). The US herds had expanded dynamically, and had larger sizes and more sows per worker than Japanese herds when the study was conducted (Koketsu, 2000). Simply put, large herds may have better production systems, herd health, and sow care programs than small herds in Japan.

The association between herd productivity and female mortality risks in high parities can be explained by a herd management difference between high-performing herds and other herds (Koketsu, 2007), including on-farm education and the culling policy. High-performing herds have better management, including intensive care with a culling policy, especially for high-parity sows, compared with ordinary herds (Stein et al., 1990a). In contrast, workers in low-performing herds are less likely to recognize a sow at risk and intervene with a treatment or make a decision to cull the sow promptly (Loula, 2000).

Limitations of this observational study are that housing, environment, genetics, and management changes, which we did not measure, could have biased our results. However, even with these limitations, this study provides practicing veterinarians and producers with useful information that can be advantageous in reducing pig mortality in commercial herds.

LITERATURE CITED


PigCHAMP DataSHARE. 2006. Summary Reports. PigCHAMP Inc., St. Paul, MN.


