Lameness in sows is a common cause for compromised animal well-being and economic loss to producers. Lame animals are likely to be unable to attain optimal breeding efficiency and may be culled before they attain their peak production. Locomotor problems are a major reason for culling in swine herds, with a reported culling rate of 15.2% in US swine herds. Sows culled because of lameness are removed at a younger age than those removed for other reasons. Early removal of sows from the herd results in lower mean litter size, number of litters per sow per year, and number of pigs weaned per sow per year, thus increasing the cost per weaned pig. The addition of new gilts into the system may also increase health risks to the animals currently in the herd. The authors of a study conducted in Germany reported fewer litters (< 3.0 litters for lame sows vs 4.5 litters for nonlame sows) and higher baby pig losses (27.7% for lame sows vs 12.4% for nonlame sows) in lame sows than in healthy sows. In that study, the financial loss associated with a lame sow to account for fewer pigs born, baby pig mortality rate, and early slaughter of sows was estimated to be 37 euros/sow ($52/ sow).

Furthermore, lame sows receive extra scrutiny when shipped to market, which decreases the salvage value. Lack of analgesics and the high labor requirement associated with providing medications for individual animals in large herds add to the fact that prevention of lameness is a better option than treatment. Despite the high prevalence of lameness in swine herds, potential measures to minimize lameness and its adverse effects have been less thoroughly explored, compared with evaluations conducted for other diseases of swine. Although lameness is extremely prevalent in breeding herds, diagnosis can be unreliable because of the lack of a criterion-referenced standard. A recent study on the sensitivity and specificity of lameness identification in sows as determined on the basis of gait abnormalities indicated that it was relatively easy to distinguish a severely lame sow from a healthy sow, but it was difficult to correctly distinguish a mildly lame sow from a healthy sow. However, early detection is critical in preventing the condition from deteriorating. Additionally, lack of observation of individual pigs for gait abnormalities is another limitation in lameness assessment in large swine herds. However, the movement of sows to farrowing facilities offers an opportunity to observe the gait of sows on most farms. Given that a severely lame animal will be culled or euthanatized if necessary, sows with less severe, chronic lameness can continue to persist in herds.

A better understanding of the effect of risk factors, including lameness, on sow productivity and longevity would augment efforts to minimize lameness in swine herds. The purpose of the study reported here was to analyze the association of lameness and performance variables with sow longevity by use of time-to-event analysis.

Materials and Methods

Animals—Large White–Yorkshire crossbred sows (n = 674) that were part of a large (> 5,000 sows) com-
commercial swine breeding herd in the Midwestern United States were used in the study, which was conducted during 2005 and 2006. The 674 sows were selected on the basis of availability of records for longevity and farrowing performance. Each sow farrowed at least once during the study period. The Institutional Animal Care and Use Committee of the University of Minnesota approved this study.

**Procedures**—Sows were entered into the study at the time of farrowing (regardless of parity) during the study period. Information on lameness was recorded once for each sow at the time of the first farrowing during the study period.

Lameness assessment was performed prior to farrowing by caretakers, who evaluated the sows while moving them to the farrowing rooms and also while the sows were housed in farrowing crates. Lame sows were identified on the basis of the ability or willingness to bear weight equally on all limbs, and the information was manually recorded on a card located by the farrowing crate of each sow. Caretakers had not received training in lameness evaluation (other than their own experiences); the authors used farm records for data on lameness and did not control the procedures of lameness evaluation. Follow-up examinations were not performed by veterinarians to confirm the lameness evaluation conducted by the caretakers.

Each sow remained in the study for up to 3 parities after the lameness assessment. Data were collected on longevity and farrowing performance for up to 350 days after the first farrowing following lameness assessment. Other information, such as parity of the sow at the time of lameness assessment, farrowing performance (numbers of pigs born alive, mummified pigs, stillborn pigs, and baby pigs that died before weaning), and longevity (removal from the herd in the form of culling, death, or euthanasia and the date of removal from the herd), was collected from the herd database.

**Statistical analysis**—All analyses were performed by use of a statistical program.

For analysis, sows were categorized as lame or nonlame sows, and parity of a sow at the time of lameness assessment was categorized as 1 and 2, 3 through 5, and > 5. Total numbers of pigs born alive, mummified pigs, stillborn pigs, and baby pigs that died before weaning (in 1 or more farrowings) during the period of ≤ 350 days were calculated and included in analyses as continuous variables.

Univariate analyses were performed for categoric (Kaplan-Meier curves and a log-rank test of equality) and continuous (Cox proportional hazard regression) variables to identify associations with sow longevity during the period ≤ 350 days after lameness assessment. Kaplan-Meier curves were used (along with the log-rank test) to verify whether survival functions were approximately parallel among strata.

For the Cox regression model, it was assumed that the hazard ratio assessed remained constant during the study period. This assumption was validated by use of the Wald test by adding interaction terms (ie, total production days and covariates) to the model. This assumption was not violated because the hazard ratio of removal was constant for the duration of the monitoring period (P = 0.125; Wald χ² test). The likelihood ratio test was used to indicate whether a factor significantly improved the fit of the model, and significance of coefficients in the models was based on results of the Wald χ² test. Tests of all the time-dependent variables (individually or collectively) did not yield significant results; thus, there was no evidence to reject the proportionality assumption.

A Cox regression analysis was performed by use of the variables significantly (P ≤ 0.1) associated with sow longevity. Total production period (≤ 350 days after lameness assessment) was the time variable. Sow longevity was the censoring variable, and a sow was considered censored when it was not removed from the herd during or after the study period (longevity = 0 indicated that a sow was censored, and longevity = 1 indicated that a sow was removed within 350 days after the initial lameness assessment).

Also, the number of pigs per day (number of pigs born alive in the second and third farrowing after lameness assessment divided by total production days) and total production days were compared between lame and nonlame sows by use of a t test. Number of lame and nonlame sows surviving at 350 days after lameness assessment was compared between lame and nonlame sows by use of a 2-sample proportion test.

The cumulative proportions of pigs born alive per day per sow farrowed among lame and nonlame sows during the production period were analyzed. For all analyses, a value of P ≤ 0.05 was considered significant.

**Results**

Univariate analyses indicated significant associations between risk factors (lameness, parity, and total numbers of pigs born alive, mummified pigs, stillborn pigs, and baby pigs that died before weaning) and sow longevity during the study. The reduction in survival function was proportional between lame and nonlame sows, and the Kaplan-Meier survivor curves were approximately parallel (Figure 1). Median survival time for lame sows was 140 days after first farrowing following the lameness assessment, whereas median survival time for nonlame sows was 302 days. Similarly, the reduction in survival functions was proportional among parity categories because the Kaplan-Meier survivor curves were approximately parallel (Figure 2). Median survival times for sows of parity 1 and 2, 3 through 5, and > 5 were 314, 302, and 167 days after first farrowing following lameness assessment, respectively. The test of equality indicated that the survival time differed significantly between lame and nonlame sows and among parity categories.

Results of survival analysis for the complete model were summarized (Table 1). There was a significant association between risk factors and sow longevity within 350 days after lameness assessment. Lame sows had a higher risk (1.710 times as high) of removal from the herd within 350 days after lameness assessment, compared with the risk of removal for nonlame sows. As the total number of pigs that died before weaning increased by 1, the risk of removal from the herd decreased by approximately 11%. For each additional pig born alive during the production period, risk of re-
mummified pig. Sows of parity 3 through 5 and > 5 had a higher risk (approx 1.579 and 1.349 times as high, respectively) of removal from the herd, compared with the risk of removal for sows of parity 1 and 2. The cumulative sum of the number of pigs born alive per sow farrowed was less for lame sows than for nonlame sows; however, this comparison was not analyzed statistically.

Mean ± SE number of pigs born alive per day was significantly \((P < 0.001)\) less for lame sows \((0.028 ± 0.003)\) than for nonlame sows \((0.049 ± 0.002)\). Survival at 330 days was significantly \((P < 0.001)\) lower in lame sows \((33/140 [23.6\%])\) than in nonlame sows \((238/534 [44.6\%])\). Similarly, mean total number of days in the herd was significantly \((P < 0.001)\) lower in lame sows \((148.30 ± 10.67)\) than in nonlame sows \((215.73 ± 4.45)\).

**Discussion**

Sow removal from a herd may not depend on biological factors of the sow alone. Other factors, such as number of gilts in the breeding herd and the market for culled sows, may also influence culling of sows in breeding herds. Nonetheless, reproductive performance is a major determinant of sow longevity because it is essential for sows to remain productive to remain in the herd. A positive relationship between productivity and sow longevity has been suggested\(^9,10\) because sow longevity is associated with the number of pigs produced per sow per year. The most commonly reported reason for unplanned sow removals is reproductive failure, which accounts for approximately one-third of all removals.\(^11\) Reproductive performance is represented by farrowing performance (numbers of pigs born alive, stillborn pigs, mummified pigs, and baby pigs that died before weaning) and breeding performance (weaning-to-estrus interval and number of breedings per conception).

The number of pigs born alive is an important performance variable in swine breeding herds because it influences the output of the herd. A reduction in the risk of removal for sows with higher numbers of liveborn pigs in the study reported here was similar

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**Table 1**—Results of survival analysis of the complete model for associations between sow longevity and lameness, parity, and farrowing performance.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Hazard ratio</th>
<th>Confidence interval</th>
<th>(P) value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. of baby pigs that died before weaning</td>
<td>0.893</td>
<td>0.832-0.958</td>
<td>0.002</td>
</tr>
<tr>
<td>Lameness (lame vs nonlame)</td>
<td>1.710</td>
<td>1.346-2.174</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Total No. of pigs born alive</td>
<td>0.839</td>
<td>0.825-0.853</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Total No. of stillborn pigs</td>
<td>0.879</td>
<td>0.829-0.932</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Total No. of mummified pigs</td>
<td>0.966</td>
<td>0.813-0.922</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 through 5 vs 1 and 2</td>
<td>1.579</td>
<td>1.186-2.102</td>
<td>0.002</td>
</tr>
<tr>
<td>&gt; 5 vs 1 and 2</td>
<td>1.349</td>
<td>1.011-1.801</td>
<td>0.042</td>
</tr>
</tbody>
</table>

*Values were considered significant at \(P \leq 0.05\).
Lameness appears to influence sow longevity directly and indirectly. Acute, severe lameness can result in immediate removal of sows from herds. However, a chronic, less severe form of lameness can affect the performance of sows and indirectly lead to sow removals. Lameness is a painful condition, and pain can influence feed intake. Cytokines released during the inflammatory process can induce anorexia and lethargy. A negative relationship between dry-matter intake and locomotion scores in dairy cattle has been reported. If a lame sow is lactating, inadequate feed intake during lactation can adversely affect the subsequent reproductive performance of that sow and eventually cause her removal from the herd. Inadequate feed intake during lactation can undermine subsequent reproductive performance of sows, such as an increase in the weaning-to-estrus interval, which can lead to removal from the herd. Sows consuming ≤ 3.5 kg (7.7 lb) of feed/d during the first 2 weeks of lactation are more likely to be removed from the herd before their next parturition.

The adverse effect of lameness on the lifetime output of pigs was also evident in the study reported here, although causality could not be established. Survival curves illustrated that the largest differences were at approximately 20 to 25 days after the farrowing following the lameness assessment, which suggested that lame sows were removed after lactation. Therefore, the reduction in the number of pigs born alive per day among lame sows could partially be attributable to fewer sows remaining in that group for subsequent farrowings. However, the median survival time in the study for lame and nonlame sows was 140 and 302 days after first farrowing, respectively. Therefore, it is clear that many lame sows had a chance to farrow a second time or, at least, were still in the herd for up to 140 days.

The higher risk of removal for lame sows detected in this study agreed with the aforementioned reports on the effects of lameness on sow longevity. The time at which lameness was diagnosed could have influenced removal decisions in this study. Even if identified as lame, a sow in advanced gestation is less likely to be removed prior to farrowing. Also, manifestations of lameness are likely to be less pronounced at the time of weaning because of the reduction in body weight during lactation, compared with effects evident during the prefarrowing period. Thus, a sow may be bred again. However, repeated incidences of lameness may result in removal from the herd as a direct effect of the severity of lameness or because of the indirect effect of lameness on reproductive performance. Although a causal link cannot be suggested, analysis of the results reported here indicated a negative effect of lameness on the number of pigs born alive over the long term. This finding contradicted the observation in another study that lameness in sows during the last month of gestation was not associated with the numbers of pigs born alive, number of stillborn pigs, or birth weights of the pigs, although the sows were only monitored until the next mating in that study.

Each farrowing is a high-risk event with regard to sow removal. In addition, farrowing can be an important risk factor for death of sows. Lameness, with a common one being the flooring of the housing system, injuries to the forelimbs and hind limbs, including lesions to the claws, are a major cause of lameness, and the risks of these injuries are higher in group-housed sows (especially if there is frequent regrouping of sows) because of aggressive interactions and increased mobility. The importance of this risk factor is likely to increase with the industry trend toward use of group pens for housing of gestating sows.

Studies conducted to evaluate the effect of litter size on longevity have also revealed a positive association between litter size and longevity in commercial herds. Obviously, the number of pigs born alive is the most influential component of litter size.

The number of liveborn pigs reportedly has a genetic correlation with the need for assistance during parturition and duration of farrowing because the number of stillborn pigs was highly correlated with the need for assistance during parturition and the duration of farrowing in 1 study. Litters of ≥ 12 pigs were 2 times as likely to contain a stillborn pig, compared with the likelihood of a stillborn pig in smaller litters. It has been reported that litter size at birth has a significant effect on the frequency of stillbirths and number of baby pigs that die before weaning. In the study reported here, the finding of a higher survivability of sows with a higher number of baby pigs that died before weaning, higher number of stillborn pigs, and higher number of mummified pigs is linked to the association of these production variables with a larger litter size.

Lameness and associated pain will adversely influence performance of lame sows that are retained in herds. It has been suggested that lameness can be associated with a reduction in fertility. A reduction in conception rate and an increase in the median number of days not pregnant have been reported in lame cattle. Lameness may also affect the ability of a sow to make postural changes within a farrowing crate and may cause death of baby pigs as a result of crushing. Another analysis of a larger database (of which the data reported here are a subset) indicated that sows retained with periparturient health problems (including lameness) had reduced longevity and fewer liveborn pigs, and fewer numbers of such sows farrowed again.

Locomotor problems are a major reason for culling. Lameness appears to influence sow longevity differently and indirectly. Acute, severe lameness can result in immediate removal of sows from herds. However, a chronic, less severe form of lameness can affect the performance of sows and indirectly lead to sow removals. Lameness is a painful condition, and pain can influence feed intake. Cytokines released during the inflammatory process can induce anorexia and lethargy. A negative relationship between dry-matter intake and locomotion scores in dairy cattle has been reported. If a lame sow is lactating, inadequate feed intake during lactation can adversely affect the subsequent reproductive performance of that sow and eventually cause her removal from the herd. Inadequate feed intake during lactation can undermine subsequent reproductive performance of sows, such as an increase in the weaning-to-estrus interval, which can lead to removal from the herd. Sows consuming ≤ 3.5 kg (7.7 lb) of feed/d during the first 2 weeks of lactation are more likely to be removed from the herd before their next parturition.

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In the study reported here, time-to-event data were analyzed by use of survival analysis and Cox regression methods. Results indicated significant differences between survivability of lame and nonlame sows in a commercial herd. Other factors influencing survivability of sows in this commercial herd were parity and farrowing performance (ie, numbers of pigs born alive, mummified pigs, stillborn pigs, and baby pigs that died before weaning). The overall performance of lame sows in terms of the number of pigs born alive during the period of the study was also less, compared with that for nonlame sows. Therefore, this study indicated the need to minimize the incidence of lameness and to remove lame sows from a herd as early as possible when treatment and recovery have a low likelihood. However, this study was based on farm records, and the diagnosis of lameness was not confirmed by a veterinarian. Similarly, there was no training program for lameness diagnosis, and the validity and reliability of the lameness assessment were not verified. However, the differences were large and suggested considerable validity for the scoring methods.

References