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Risk factors associated with endemic reproductive deficiencies caused by PRRSV infection

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Summary

Objective: To describe chronic reproductive losses and determine associated risk factors in swine herds positive for porcine reproductive and respiratory syndrome virus (PRRSV) in the midwestern United States.

Methods: Twenty-seven PRRSV-positive breeding herds were monitored for 6 months before and 1 year after the PRRSV outbreak. Herds were statistically analyzed and assigned to one of two herd PRRSV statuses: either "recovered" if measured reproductive parameters returned to pre-outbreak levels, or "chronic" if ≥ 2 reproductive parameters did not return to at least 90% of pre-outbreak levels. Data regarding herd attributes and management practices prevailing in the herds were collected via a producer survey. Multifactorial logistic regression analysis was applied to determine associations between management practices or herd attributes and the PRRSV status of the herd.

Results: Seven of 27 herds (26%) were categorized as chronic PRRSV-positive breeding herds, while the other 20 were categorized as "recovered." Two logistic models were produced for the chronic herds: one containing management factors statistically associated with a chronic PRRSV status (raising own replacement gilts, isolation of new breeding stock, number of sows per farrowing room, and inventory of growing pigs), and one identifying herd attributes (parity and sow inventory) that were associated with a chronic PRRSV status.

Implications: PRRSV-positive herds can have chronic reproductive losses in which some reproductive parameters will not return to 90% of prediagnosis levels. Certain herd attribute/management factors are associated with increased or decreased risk.

Keywords: swine, PRRSV, reproduction, management

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The prevalence of porcine reproductive and respiratory syndrome virus (PRRSV) in swine herds in the United States and Canada has been estimated to range between 14%–82%.[1–3] Outbreaks of PRRSV are usually characterized by a period of severe reproductive problems in the breeding herd followed by a return to near-normal levels of reproductive performance, punctuated by recurrent episodes of reproductive failure.[4–7] Investigators have reported reduced farrowing rate, increased numbers of stillborns and mummified fetuses, and increased preweaning mortality rates as commonly associated with PRRSV outbreaks.[4–7] Most herds eventually return to pre-outbreak levels of reproductive performance,[8] but some herds never resume pre-outbreak performance levels.

Various studies have suggested many possible explanations for the variability in the impact of PRRSV on herds:

- variation among isolates under field conditions;[9–11]
- pockets of PRRSV-naive animals within a herd;[12–15]
- housing and stocking density effects on the probability of transmission by nose-to-nose contact and aerosol transmission;[16–18]
- variability in herd type and size, pig flow strategies, and pig densities;[13,19,20]
- use of artificial insemination (AI);[21]
- use of disinfectants and other cleaning protocols;[20,22]
- use of certain biosecurity practices in a herd;[23–29] and
- use of PRRSV vaccines.[30–33]

No epidemiologic studies have been conducted to analyze how herd attributes and management factors might be associated with failure in a herd to return to pre-PRRSV-outbreak reproductive performance. In this epidemiologic study, we used PigCHAMP® records spanning 18 months and data collected in a producer survey, to analyze the statistical association between various management and herd attributes and a chronic PRRSV status in midwestern swine herds.

Materials and methods

PigCHAMP® and producer survey data was collected as previously described.[8]

Monthly Performance Monitor reports were generated in PigCHAMP® and were subdivided into four time frames relative to the initial outbreak of PRRS in the herd (Figure 1):

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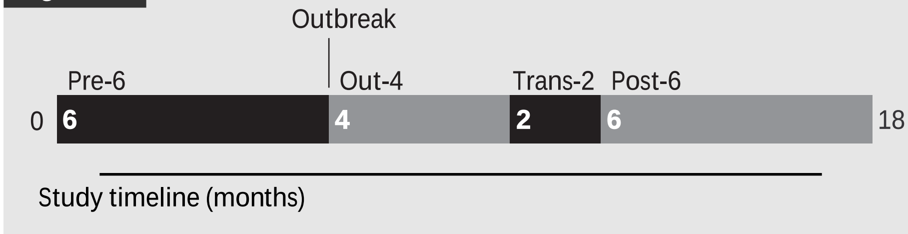
- pre-6 (the 6 months prior to the initial outbreak, ending on the day the PRRS outbreak was diagnosed);
- out-4 (the 4 months immediately following the initial diagnosis);
- trans-2 (the 2 months after the 4-month outbreak); and
- post-6 (the 6 months after the transition period).

Figure 1



In this way, the post-6 period covered the same calendar months as the pre-6 period, to avoid confounding from season etc.

We then categorized the PRRS status of the herds using the four reproductive parameters most commonly reported[4–7] as being associated with PRRSVoutbreaks:

- farrowing rate,
- number of stillborn,
- number of mummified fetuses, and
- preweaning mortality

across the four subperiods.

Herds whose reproductive performance during the post-6 period did not achieve levels at least 90% of what that herd achieved during the pre-6 period for at least two of the four measured reproductive parameters were labeled "chronic" herds. All other herds were labeled "recovered." Herds were categorized as either chronic or recovered on a herd-by-herd basis.

Reproductive performance over time

Basic reproductive performance of these herds was monitored across these four subperiods 18 of the reproductive parameters included on PigCHAMP® Performance Monitor reports, as previously described.[8] These parameters were analyzed in all 27 PRRSV-positive herds using Student's t-tests to determine statistical differences ($P<.05$) among the four subperiods surrounding the outbreak date.

Calculating risk of remaining chronic for PRRSV

We performed a χ^2 analysis to test for simple associations between the PRRS status of the herd (chronic versus recovered) and the various herd management and attribute factors from the survey.

Two logistic models were then created — one for producer survey data and one for PigCHAMP® data — using PC/SAS®(SAS Institute, Cary, North Carolina). Threshold dummy variables representing

- number of sows farrowed per room,
- inventory of growing pigs, and
- sow inventory

were created using the Walter's technique to include in the logistic regression analysis.[34] These three dummy variables compensated for the population variability among herds. Chronic status was regressed on each of the threshold variables and the other variables that emerged as significant ($P < .20$) from the χ^2 test. (Because of the small sample sizes, we used the higher P value to ensure that significant variables were not excluded from the models.[35]) Models were built using a backward elimination approach.[35]

From the logistic model output provided by PC/SAS®, the inverse log of the parameter estimate was calculated to obtain the odds ratio (OR). For breeding herd inventories, we analyzed the risk for each size category (i.e., < 100 sows, 101–300 sows, 301–400 sows, 401–500 sows, 501–600 sows, 601–700 sows, ≥ 701 sows) compared to all the smaller categories combined. Thus, for example, all herds in the study with ≥ 701 sows were compared to all the smaller herds combined (i.e., all the other herds in the study).

Results

Reproductive performance over time

For the herds included in this study, reproductive performance in the post-6 period never achieved pre-6 levels (Figure 2) for most parameters measured. ANOVA was used for the initial analysis to compare among multiple variables. For example,

- farrowing rate,
- average pigs born alive/litter,
- pigs weaned/inv. female/year, and
- litters/mated female/year

were all significantly higher in pre-6 period than in the post-6 period ($P < .05$).

In the post-6 period,

- weaning–1st service interval,
- total stillborn pigs,
- pre-weaning mortality,
- death rate, and
- ave non-productive sow days

were all significantly increased compared to the pre-6 period.

The number of females bred by 7 days improved significantly overall when the pre-6 period was compared to the post-6 period (Figure 2). Weaning ages decreased significantly, and average farm sow numbers increased significantly during the study period.

Weaning-1st-service interval was significantly increased in the post-6 period compared to the immediate outbreak (out-4) period, as well (Figure 2). Preweaning mortality was highest during the out-4 period, and, although it decreased again during the trans-2 and post-6 period, never returned to pre-6 levels ($P < .05$).

Herds' PRRS status

Seven of the herds included in the study (26%) were categorized as "chronic," because at greater than or equal to two of the four reproductive parameters we monitored did not return to at least 90% of pre-6 performance during the post-6 period. The other 20 recovered herds returned to virtually normal reproductive performance by the post-6 period.

Reproductive performance decreased during the out-4 period in both chronic herds and recovered herds for the following parameters (Figure 3):

- farrowing interval,
- farrowing rate,
- average stillborn pigs,
- average mummies per litter, and
- pre-weaning mortality.

Many of the reproductive parameters we measured began to return to pre-6 levels during the trans-2 period (Figure 3), with only

- weaning - 1st service interval, and
- farrowing interval

differing significantly between the pre-6 and trans-2 period.

We observed significant differences between pre-6 and post-6 performance in six of the seven chronic herds (85.7%) for the mean stillborn and preweaning mortality parameters. In five of the seven chronic herds, farrowing rate also did not return to 90% of pre-outbreak levels.

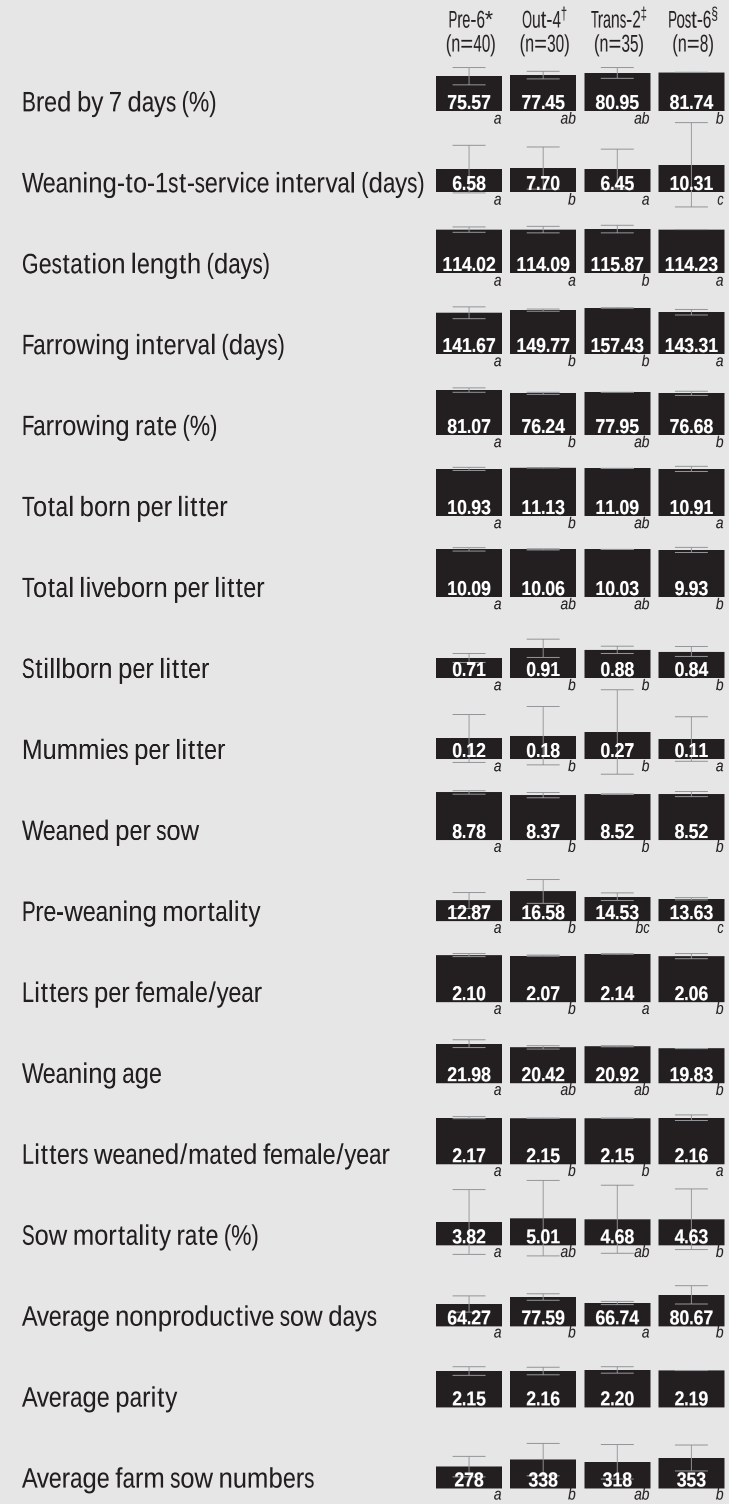
Management factors associated with chronic PRRS status

The χ^2 analysis identified 13 herd management/attribute variables to include in the logistic model ($P < .20$) (Table 1); the other variables did not show statistical association with chronic PRRS status in this study.

Of these 13 variables, six remained significant ($P < .20$) after logistic analysis was performed (Figure 4), including:

- raising gilts for replacements: if gilts were

Figure 2



Breakdown of reproductive performance in PRRS-positive herds by period surrounding initial outbreak, based on monthly averages (± SD)

abc Variables with different subscripts differ significantly ($P < .05$).

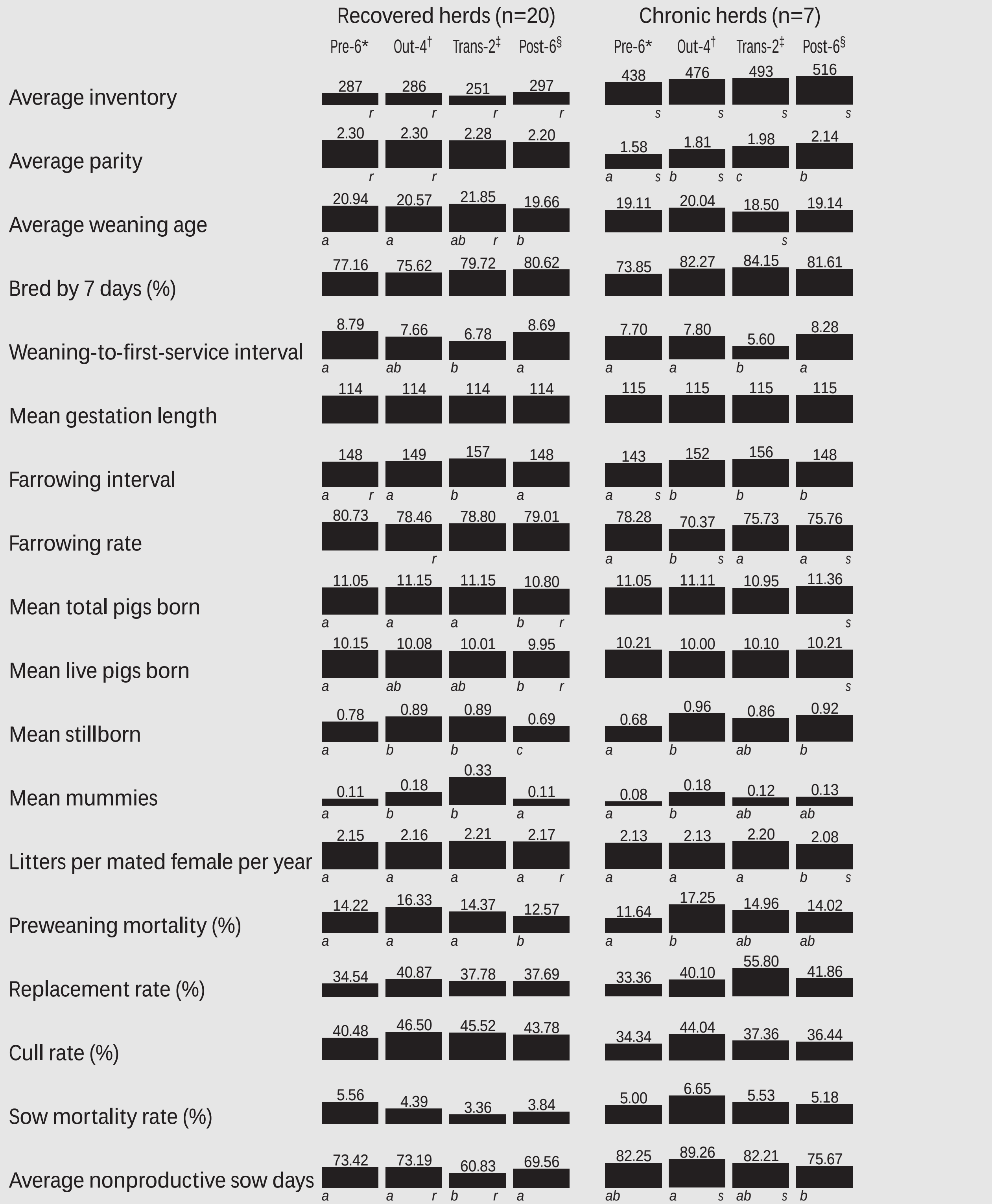
* 6 months preceding the initial PRRSS diagnosis

† 4 months immediately following the initial PRRS diagnosis

‡ 2 months of transition between the 4-month outbreak period to the 6-month post-outbreak period

§ 6 months after the outbreak/transition period

Figure 3



Categorical analysis of the herd performance of recovered and chronic PRRSV-positive breeding herds surrounding the outbreak date

abc Means within the same PRRS category with different subscripts differ by P<.05
rs Means between PRRS categories (recovered versus chronic) with different subscripts differ by P<.05
* Pre-6 = 6 consecutive months prior to the PRRS diagnosis date
† Out-4 = 4 consecutive months starting at the PRRS diagnosis date
‡ Trans-2 = The fourth and fifth month following the outbdiagnosis reak date
§ Post-6 = The sixth through the eleventh month following the diagnosis date. Corresponds to the same calendar months as Pre-6

Table 1

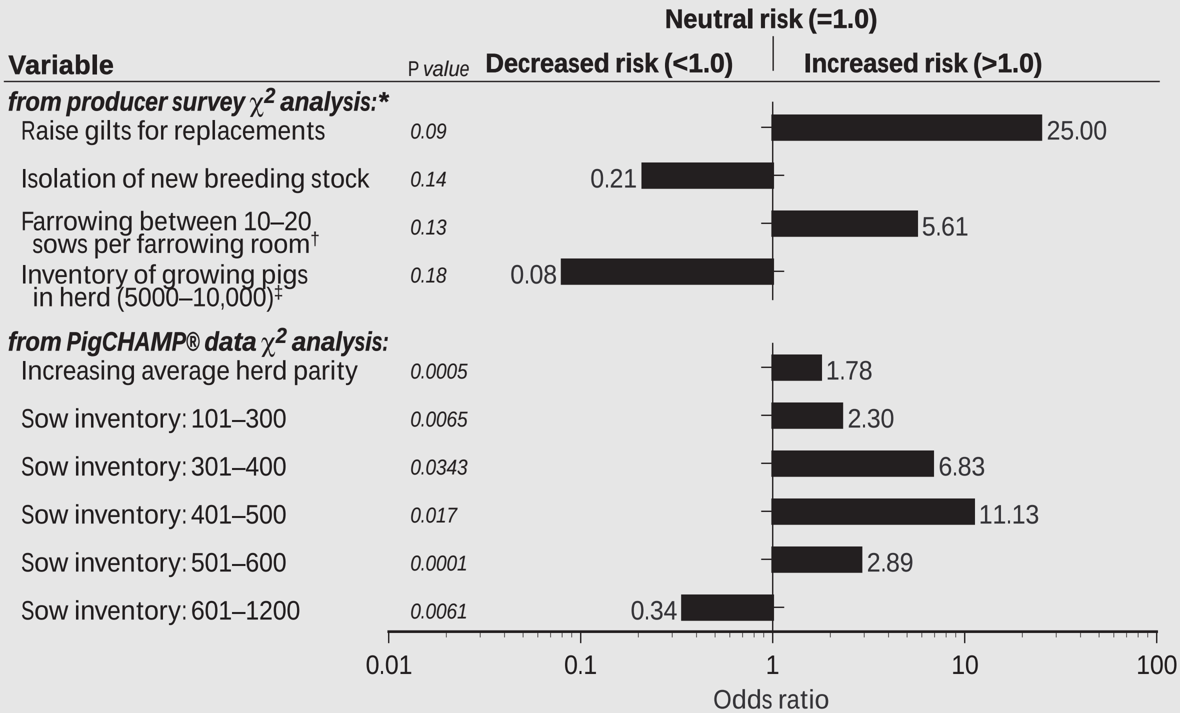
Factors associated with PRRSV-positive swine herds that have chronic suboptimal reproductive performance and factors **not** associated with PRRSV-positive swine herds that have chronic suboptimal reproductive performance

Variable[a]	*P*
Vaccination	
Gilts vaccinated for PRRSV[b]	.140
Boars vaccinated for PRRSV[b]	.060
Piglets vaccinated for PRRSV[b]	.230
Nursery pigs vaccinated for PRRSV	.535
Animal source	
Purchasing gilts from outside sources[b]	.060
Purchase boars from >1 source	.756
Purchase boars from 1 source	.756
Raise own boars	.963
Purchase gilts from >1 source	.547
Facility design	
Breeding indoors[b]	.100
Gestating indoors[b]	.100
Number of sows per farrowing room[c]	.080
Mix breeding and growing pigs in same building	.385
Breed females in crates vs. pens	.439
Multisite production	.963
Biosecurity	
Not providing coveralls & boots for visitors[b]	.140
Isolation of new breeding stock[b]	.110
Serologically test breeding stock prior to entry[b]	.200
Isolation of new breeding stock > 30 days	.963
Isolation of new breeding stock > 60 days	.573
Separate employees and equipment on multisite units	.963
Three or greater swine herds within 2-mile radius	.535
Two swine herds within 2-mile radius	.853
One swine herd within a 2-mile radius	.756
Zero swine herds within a 2-mile radius	.963
Shower-in–shower-out	.853
Perimeter fencing used	.277
Visitors —Time away from pigs (any amount)	.963
Management	
Average sow inventory[c]	.001
Growing pig inventory[c]	.110
Average parity[c]	.001
Farrow all-in–all-out (AIAO)	.756
Use disinfectants	1.00
Management: Breeding	
Use any AI	.590
Use 100% AI	.765
Use greater than 75% AI	.963
Use 26 to 74% AI	.573
Use 25% or less AI	.963
Using no AI	.756

significant
not significant

a Variables entered into logistic regression model (Figure 4).
b Comparison made using χ^2 test with 1 degree of freedom.
c Comparisons made using t-test.

Figure 4



The association between having endemic reproductive losses due to PRRSV and management decisions, herd size, or parity distribution

* Due to small sample sizes, the *P* value for producer survey variables that emerged from the χ^2 were set at $P < .20$ to enter the logistic regression model

† The referent group was farrowing greater than 20 crates per farrowing room

‡ The referent group was growing pigs inventories of less than 5000

raised for replacement animals, herds were 25 times more likely to be chronic than if gilts were purchased;

- isolating new breeding stock: the isolation of new breeding stock prior to herd entry reduced the risk of a herd remaining chronic (OR = 0.21);
- farrowing between 10–20 sows per farrowing room (versus farrowing more than 20 sows per farrowing room): herds with 10–20 farrowing crates per room were 5.6 times more likely to be chronic than herds with greater numbers of crates per room;
- having an inventory of 5000–10,000 growing pigs (versus having an inventory of < 5000): a growing pig inventory of 5000–10,000 (OR = 0.08) reduced the risk of a herd being classified as chronic;
- having an increasing average herd parity: as parity increased, the risk of a PRRSV-positive breeding herd being chronic was magnified (OR = 1.78); and
- having sow inventories >101–1249 sows (versus ≤ 100 sows): The largest herd was 1249 sows and the smallest was 22 in this study. Compared to herds of 100 sows or less:
  —inventories of 101–300 were 2.3 times (OR = 2.30) more likely to be chronic;
  —inventories of 301–400 were 2.97 times (OR = 2.97) more likely to be chronic than all smaller herds;
  —inventories of 401–500 sows were 1.63 times (OR = 1.63) more likely to be chronic when compared to all smaller herds;
  —an inventory ≥ 501 sows slightly reduced the risk (OR = 0.26) of remaining chronic compared to all smaller herds; and
  —inventories of ≥ 601 sows had a slightly reduced risk (OR = 0.12) compared to all smaller herds.

The management variables that were not significantly associated with chronic herd status after controlling for isolation of gilts, raising replacement gilts, and farrowing room size were:

- vaccination with PRRSV vaccine,
- purchasing gilts from outside sources,
- facility considerations,
- herd visitor biosecurity, and
- serological testing.

Discussion

Odds ratios describe the probability that an event will occur compared to that of it not occurring. In this study, the odds ratios estimated the probability that a herd would have a chronic PRRS status if it also had the herd characteristic or management variable of interest, e.g., raising its own replacement gilts. Odds ratios > 1.00 indicate that the management variable carried an increased risk of being associated with chronic PRRS status, while odds ratios < 1.00 are associated with a decreased risk of chronic PRRS.[35]

Finding "statistically significant" associations in a particular logistic regression model or study does not establish a causal relationship.[35] For example, the statistically significant findings related to herd size in this study may correspond to the improved management or incorporation of technologies by the larger herds. However, to establish a causal link, variables that are associated require further research in follow-up studies.

Our small sample size influenced the power of this study to identify significant variables. Additionally, some of the management factors reported by the survey respondents may have been initiated as a reaction to the PRRS outbreak. The reduction in the number of parameters that differed between the trans-2 and post-6 periods compared to the number that differed between the pre-6 and post-6 period may not necessarily indicate that the trans-2 period was associated with reproductive parameters returning to levels normal for that herd; instead, it may be explained by the large interherd variation in productivity.

In all of the chronic herds and most of the recovered herds, gilts and boars were being vaccinated against PRRSV. Although we observed simple associations between chronic PRRS status and vaccinating for PRRSV (Table 1), after controlling for other variables there was no association between vaccinating for PRRSV and chronic PRRS status. Reports from various field cases suggest that use of the vaccine in pregnant animals may result in reproductive losses.[30] The PRRSV vaccine available for use at the time of this study was not approved for use in gestating sows. Vaccine virus transmission has been documented, as measured by seroconversion on the PRRSV ELISA, via nose-to-nose contact.[36]

In this study, herd size played a role in the risk of a herd remaining chronic for PRRS. As sow inventories increased from 500 to 700 sows (in 100-sow increments), chronic reproductive signs decreased. It has been shown with pseudorabies virus (Aujeszky's disease virus) that there is a threshold in breeding herd inventory at which endemic disease is more prevalent.[37] Perhaps the increased likelihood that larger units will incorporate new technologies accounts for our observation that the risk of remaining chronic for PRRS was reduced in herds with > 500 sows. New management technologies including AIAO, multiple-site rearing, segregated early weaning, and AI improve health, lower costs, and reduce financial risk.[38]

Our observation that farrowing between 10–20 sows per room increased the odds of a herd remaining chronic over all other farrowing room sizes is related to the sow inventory variable we found significant in our study. It may indicate the ability of infectious organisms to spread more evenly throughout a larger population within the >20 sows per farrowing room. Also, herds with fewer sows per farrowing room may indicate smaller producers who have incorporated less technology and fewer biosecurity measures.

Maintaining an inventory of 5000–10,000 growing pigs was associated with a reduced odds ratio of 0.08. This may also be a reflection of the slight reduction in risk when a herd maintains a sow inventory of ≥ 501 sows. The percentage of herds that remained chronic for PRRS were noticeably reduced when growing pig inventories increased from 5000–10,000 head. Larger herds may be more successful at incorporating management technology and biosecurity measures that decrease disease problems.

In this study, increasing parity was associated with a chronic PRRS status. One theory may be that antibody-dependent enhancement occurs. Antibody-dependent enhancement is defined as an increased risk of infection and disease that occurs from a decline of antibody below protective titers.[39,40] Therefore, as antibody titers from natural exposure or immunization decline, there might be an increased incidence of reinfection. This would potentially occur in herds with steadily increasing parities since PRRSV antibody titers decline over time. Antibody titers from PRRSV can be detectable for as few as 4 months but may be detectable for as long as 604 days.[32] Therefore, older parities may not be associated with the same advantages for PRRSV as has been observed with other infectious organisms.

For herds raising their own gilts for herd replacement, risk of retaining a chronic PRRSV status was increased by 25 times. Serological sampling to demonstrate antibody decay over time has identified seronegative subpopulations within breeding herds.[15] It is important that the serological status of incoming gilts and stability of the existing breeding herd be known. Only two of the seven (28.6%) chronic herds in this study serologically tested incoming breeding stock.

Isolating new breeding stock reduces the risk of a herd remaining chronic (OR=0.21). Data from a 1995 NAHMS epidemiological study[29] indicated only 37.4% of pork producers in 16 states (representing 91% of the United States hog inventory) isolated breeding female swine prior to entry into the existing herd. Swine industry specialists strongly advocate that incoming breeding stock be isolated as a technique to prevent infectious organisms from being introduced into a herd.[27,41,42] The duration of the isolation period was not a significant factor in this study even though a 60-day isolation period has been advocated.[24] PRRSV may be maintained in the oropharyngeal area of infected swine for up to 157 days post infection, making a 60-day isolation period inadequate.[43,44] Isolation may not create a significant reduction in risk of infection, but may be characteristic of a higher degree of management or biosecurity.

Caution should be exercised when generalizing the results of this study to the swine industry at large. The herds included in this study were not selected at random — they were provided by veterinarians who were members of the AASP. Thus, the producers who participated all used consulting veterinarians, which probably influenced management and disease levels. The dataset was comprised of PigCHAMP® users who were willing to share their production data and to complete the survey. Thus, these results should be interpreted and generalized only to herds owned by cooperative, record-conscious producers. However, the productivity of the herds included in this study was similar to that of other midwestern herds; the reproductive performance we observed in the negative herds was within normal reported ranges.[14] The replacement and culling rates were also within suggested ranges for progressive swine herds.[14]

This study suggests that several management practices are associated with chronic PRRSV infections that compromise reproductive performance. It is unfortunate that only 27 herds, with only seven chronic herds, are represented in this study. Whether these parameters are significant throughout the swine industry needs to be assessed on a wider scale. This study should initiate further risk factor analyses.

Implications

- Buying gilts for replacements may reduce the risk of remaining chronic for PRRS, but the immunological status of new introductions should be assessed and quality of biosecurity measures maintained for all incoming animals.
- Larger herds were at a greater risk of remaining chronic for PRRSV; however, that risk was eliminated when breeding herd inventories exceeded 701 sows.
- If the prevalence of chronic PRRSV status observed in this study represents the general swine population, approximately 25% of herds with reproductive losses due to PRRSV will remain chronic.

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