Case-control study of factors associated with excessive proportions of early fetal losses associated with mare reproductive loss syndrome in central Kentucky during 2001

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Central Kentucky is one of the largest Thoroughbred breeding epicenters in the world with more than 20,700 mares bred in 2001. The equine industry contributes $3.4 billion to the Kentucky economy and is one of the largest industries in the state. Thus, farm veterinarians and managers, diagnostic laboratory personnel, and extension veterinarians take care in monitoring for outbreaks of any type of disease, including outbreaks of abortion. Historically, most aborted fetuses in central Kentucky have been submitted to the University of Kentucky Livestock Disease Diagnostic Center (LDDC) in Lexington for complete diagnostic and pathologic examinations, as the LDDC does not charge a fee for livestock necropsy.

Because of the intensive breeding schedules in central Kentucky, especially on Thoroughbred and Standardbred farms, mares are palpated per rectum and have ultrasonographic examinations performed regularly for pregnancy determination and to monitor fetal viability and development. Most mares are palpated or have ultrasonographic examinations at 42 days of gestation for fetal insurance purposes. Several farms also have veterinarians perform ultrasonography on mares at 60 to 65 days of gestation for fetal sex determination.

The occurrence of a markedly increased number of early fetal losses (EFLs) was brought to the attention of extension veterinarians at the University of Kentucky’s Maxwell H. Gluck Equine Research Center on May 1, 2001. Veterinary practitioners reported that an excessive number of previously pregnant mares were found to no longer be pregnant at 60 days of gestation.

Rectal palpation findings were normal; however, on ultrasonographic examination of affected mares, the fetus was either absent, present but dead, present but with slow heart rate and movements, or present but with slow heart rate and movements but with no visible fetal parts. Because of the intensive breeding schedules in central Kentucky, especially on Thoroughbred and Standardbred farms, mares are palpated per rectum and have ultrasonographic examinations performed regularly for pregnancy determination and to monitor fetal viability and development. Most mares are palpated or have ultrasonographic examinations at 42 days of gestation for fetal insurance purposes. Several farms also have veterinarians perform ultrasonography on mares at 60 to 65 days of gestation for fetal sex determination.

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Results

Factors significantly associated with an increased risk of excessive early fetal losses were exposure to moderate to high concentrations of Eastern tent caterpillars, exposure to cherry trees, farm size ≥ 50 broodmares, being bred during February 2001, and frequent exposure to waterfowl. Feeding hay to mares outside was associated with a decreased risk of excessive proportions of early fetal losses. Pasture composition and management factors were not significantly different between affected and control pastures. Individual animal-level factors were investigated on 6 farms representing 340 mares, and age, parity, and pre- and postbreeding treatments were not significantly associated with risk of early fetal loss.

Conclusions and Clinical Relevance—Results suggest that limiting exposure to Eastern tent caterpillars and cherry trees and feeding hay to mares outside may help decrease the risk of excessive proportions of early fetal losses associated with mare reproductive loss syndrome. (J Am Vet Med Assoc 2003;222:613–619)
Materials and Methods

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Materials and Methods

Study design—A case-control study was conducted to identify factors related to excessive fetal losses on horse farms in central Kentucky during 2001. Epidemiologists discussed the fetal loss problem with veterinarians, basic scientists, and farm managers to gain an appreciation for the magnitude of the problem. A questionnaire was developed by a group of epidemiologists, animal scientists, veterinarians, reproductive physiologists, and an economist. Additional input on questionnaire design and administration was solicited from local veterinarians, farm managers, members of the equine industry, and other researchers. All questionnaires were administered on the farm by 23 volunteers, each of whom visited 6 to 7 farms.

A list of 156 Thoroughbred farms willing to participate in further MRLS studies was available from a previous survey conducted through a local farm managers club on May 7, 2001. Since most of these farms had experienced problems with MRLS, additional Thoroughbred farms with few or no fetal losses attributable to MRLS were needed for comparison. These were identified through telephone calls to veterinarians and farm managers. Farms with Standardbred mares or equids of other breeds were also solicited to participate in the study by telephoning several equine practices in the central Kentucky area.

To be eligible to participate in the study, farms had to have ≥ 20 broodmares, and veterinarians had to have performed ultrasonographic examination on broodmares prior to 45 days of gestation and again at 60 days of gestation or later. A list of 130 farms that fit these study criteria was created. It became apparent early in the course of the study that the principle manifestation of MRLS on the recruited farms was EFLs. Therefore, although the occurrence of LTAs was recorded, the focus of analyses of data obtained through the case-control study was EFLs.

A 3-tiered approach to data collection and analysis was used. A general questionnaire was designed to collect farm- and pasture-level data. Farm-level data related to farm management practices and demographic information. Case farms included those on which owners and managers perceived EFLs to be in excess of what they considered normal for their farms in comparison with the previous few years. Control farms were those for which owners and managers reported losses typical for their farms. For pasture-level data, the 1 pasture on each affected farm with the highest number of EFLs was selected as a case pasture. Control pastures consisted of the 1 pasture on each control farm with the greatest number of at-risk mares but no excess EFLs. This portion of the questionnaire included questions regarding pasture treatments, grass types, types of trees present, and other factors related to pasture management.

An additional questionnaire was administered on 6 case farms with ≥ 50 mares at risk. This questionnaire was designed to collect data (including age, parity, breeding status, and any medications that had been administered and may have been associated with EFL) on individual animals. All horses on these farms that were bred between February 10 and April 1, 2001 and confirmed to be pregnant by ultrasonographic examination prior to 45 days of gestation were included. Case horses were horses confirmed by means of ultrasonographic examination at 60 days of gestation or later to no longer be pregnant. Control horses were horses confirmed to still be pregnant after 60 days of gestation.

Study implementation—A training session was held for all study personnel during which questionnaires were reviewed and terminology used in the document was discussed. Confidentiality agreements for the farms were attached to the questionnaires, and farms were identified by farm number only. Data collectors were the only personnel who received both the names and identification codes of the farms for which they were responsible, since confidentiality was an important concern for the participating farms.
project coordinator retained the key to all farm names and identification codes.

Data collection was started in May 2001, 3 weeks after the initial idea for the study was conceived, and data collection was completed in 19 days because of the urgency of the situation. Data collectors contacted farm managers or owners for an appointment and completed the questionnaire with the farm manager or another representative from the farm. Photographs of affected and control pastures were taken to document pasture conditions, surface water, and tree composition.

Covariates calculated for each level of the horse-level factors of interest. Lemeshow (HL) statistic for 1 model parameter at a time was used to select variables for the final model with a P value ≤0.05 required to remain in the final model. The Wald test and z-statistic for 1 model parameter at a time was used to select variables for the final model with a P value ≤0.05 required to remain in the final model.

The proportion of mares that experienced EFLs was calculated for each level of the horse-level factors of interest. Odds ratios were calculated, and significance was determined with the x² test. Variables with an odds ratio ≥2 or ≤0.5 and a P value ≤0.20 were considered eligible for multivariable logistic regression modeling with backward elimination, in which pasture status was the response variable.5 The Wald test and z-statistic for 1 model parameter at a time was used to select variables for the final model with a P value ≤0.05 required to remain in the final model.

The clustered nature of the horse-level data (ie, horses within farm) was accounted for by use of the Taylor series technique,i and goodness of fit was evaluated with the Hosmer-Lemeshow (HL) statistic without accounting for clustering in the horse-level data.

Results

Of the 150 farms eligible for inclusion in the study, 133 (88%) in 10 counties participated. Thoroughbred, Standardbred, American Saddlebred, and Morgan Horse farms were represented. Reasons cited for nonparticipation were lack of time because of being too busy with breeding stallions, illness of the farm manager or family members, or the farm manager being absent from the farm. The number of broodmares per farm at the time of data collection ranged from 11 to >300 (mean, 126; median, 93).

Of the 133 farms that participated in the survey, 97 were classified as having excessive EFLs (ie, owners and managers perceived EFLs to be in excess of what they considered normal for their farms in comparison with the previous few years). Of these, 66 had excessive EFLs but normal proportions of LTAs, 30 had excessive EFLs and LTAs, and 1 had excessive EFLs but was not at risk for LTAs because no mares were in late pregnancy at the time of the survey. The remaining 36 farms were classified as control farms (proportion of EFLs was not considered excessive, compared with previous years). Four of these farms reported having excessive LTAs but were included in the control group as they did not have excessive EFLs.

Farm-level results—On EFL-affected farms, 79.7% (n = 2,233) of mares that were pregnant at 45 days of gestation underwent ultrasonographic examinations at ≥60 days of gestation. Of these, 38.4% (1,304) of mares were still pregnant and had normal ultrasonographic examination results, 6.0% (133) were pregnant but had abnormal uterine ultrasonographic examination results, and 35.6% (795) were not pregnant. On control farms, 89.7% (n = 501) of mares that were pregnant at 45 days of gestation underwent ultrasonographic examinations at ≥60 days of gestation. Of these, 86.6% (n = 434) were still pregnant and had normal ultrasonographic examination results, 3.6% (18) were pregnant but had abnormal uterine ultrasonographic examination results, and 9.8% (49) were not pregnant. Mean percentages of mares no longer pregnant at the time of ultrasonographic examination at ≥60 days of gestation were 35.9% for case farms (median, 37.9%) and 8.9% for control farms (median, 7.3%). Thirteen of 929 (1.4%) mares on case farms and 1 of 67 (1.5%) mares on control farms had signs of illness prior to an abnormal ultrasonographic finding.

Factors associated with farms having excessive proportions of EFLs included having ≥50 mares on the farm (P = 0.01; Table 1), the presence of a high concentration of caterpillars (P < 0.001), and the frequent presence of waterfowl (P < 0.001). The only factor associated with a lower risk of EFLs was feeding hay outside, whether on the ground or in mangers or other devices (P = 0.006). Factors not associated with increased EFLs were water source; method of delivering drinking water; ground moisture level; time on pasture during the day or night; percentage of total ration made up by pasture; being held off pasture from April 15 through 25; mowing practices before, during, and after the frosts of April 17 and 18; spreading manure on pastures; fertilization during fall 2000 or spring 2001.
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EFLs were pasture type including herbicide applications to pastures was very low, and no with increased percentages of EFLs. The number of practices during April did not indicate any association clover in pastures (10, 20, or Additional analyses combining factors for percentage of evergreens, or deciduous trees other than fruit trees in type fertilizer; pasture treatment with lime in 1999, 2000, or 2001; treatment of pastures with herbicides or pesticides during spring 2001; forage type (fescue, orchard grass, bluegrass, clover, or other grasses); percentage (10, 20, or > 40%) of clover in pastures combined with mowing practices during April; ragweed in pastures; percentage of edible vegetation in broadmire pastures; source of hay; hay from a 2000 or 2001 crop; grain fed to mares inside or outside; type of grain concentrate (unpelleted sweet feed, unpelleted grain, complete feed pellets or cubes, or grain or sweet feed mixed with pellets); grain contamination by wild or domestic animals' feces; source of grain (bag, bulk, or home grown); type of bedding used; exposure to wildlife including rodents, raccoons or skunks, coyotes or foxes, deer or elk, and bats or opossums; wild animal exposure to stored grain or hay; domestic animal exposure to stored grain or hay; insect control measures (on horses and in barns, pastures, trees, and feed).

Pasture-level results—Information from 95 affected pastures and 47 control pastures was analyzed. Two pasture-level factors were significantly associated with excessive EFLs: the presence of moderate or high caterpillar concentrations (P < 0.001; Table 2) and pastures containing barren or maiden mares bred in 2001 (P = 0.004). This model exhibited good fit with the data (P = 0.93). Factors not associated with the number of EFLs were pasture type including > 40% of any type of grass; presence of ragweed; quality of forage; manure (composted or not composted) spread on fields; chain harrowing of pastures; supplemental hay fed; pasture mowing before, during, or after the frosts of April 17 and 18; fertilization in fall 2000 or spring 2001 with any type fertilizer; pasture treatment with lime in 1999, 2000, or 2001; presence of fruit trees (besides cherry), evergreens, or deciduous trees other than fruit trees in or around pastures; and surface water in pasture. Additional analyses combining factors for percentage of clover in pastures (10, 20, or > 40%) with mowing practices during April did not indicate any association with increased percentages of EFLs. The number of herbicide applications to pastures was very low; and no pastures were sprayed with pesticides.

Mare-level results—Mares on the 6 farms for which individual horse data were collected ranged from 2 to 22 years old (mean, 7.8 years; median, 7.0 years). Parity ranged from 0 to 14 (mean, 2.5; median, 2.0). Of the 340 mares included in this portion of the study, 91 were maiden, 82 were barren, 162 had foaled in 2001 and were bred in 2001, and 5 had an unknown breeding status. Mare-level factors associated with excessive proportions of EFLs included being bred in February (P = 0.003, Table 3) and having been exposed to cherry trees (P = 0.04). This model exhibited acceptable fit with the data (P = 0.35). Mare-level factors that were not associated with EFLs included the mare’s state of origin (Kentucky vs another state), age, prebreeding uterine infection, postbreeding uterine infection, status at 2001 breeding (maiden, barren, or foaled in 2001), parity, medications administered (hormonal treatments, antimicrobials, nonsteroidal anti-inflammatory drugs, or other drugs), use of probiotics or mycotoxin binders in feed, administration of rotavirus or herpesvirus vaccine (killed or modified-live virus vaccine), number of hours on pasture per day (day or night), any illness prior to breeding or during pregnancy, and caterpillar concentration in the mare’s environment.

Discussion

The goal of this study was to identify factors associated with MRLS in the hope that these factors could be used to direct future research activities toward finding a cause and preventing future occurrences of this new disease. Because of the low numbers of farms that only had LTAs, conclusions from these data are best limited to farms and pastures housing horses with EFLs or both EFLs and LTAs and to individual mares with EFLs. Results of the analyses performed in the present study indicated 5 factors associated with an increased risk of having excessive proportions of EFLs: farms having ≥ 50 mares, farms with frequent exposure to waterfowl, moderate to high concentration of caterpillars on farms and in pastures, mares with breeding

Table 1—Farm-level factors associated with excessive proportions of early fetal losses on horse farms in central Kentucky during 2001

<table>
<thead>
<tr>
<th>Factor</th>
<th>Case farms (%)</th>
<th>Control farms (%)</th>
<th>Adjusted OR*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm size ≥ 50 mares</td>
<td>66.0</td>
<td>38.9</td>
<td>3.2</td>
<td>1.3–7.7</td>
</tr>
<tr>
<td>High caterpillar concentration</td>
<td>67.0</td>
<td>22.2</td>
<td>6.4</td>
<td>2.5–16.9</td>
</tr>
<tr>
<td>Frequent presence of waterfowl</td>
<td>60.8</td>
<td>25.0</td>
<td>5.6</td>
<td>2.2–14.3</td>
</tr>
<tr>
<td>Feeding hay outside</td>
<td>82.1</td>
<td>91.4</td>
<td>0.19</td>
<td>0.06–0.61</td>
</tr>
</tbody>
</table>

*Each factor was examined individually using logistic regression with farm size, presence of cherry trees, and caterpillar concentrations included as covariates when these factors were not the factor of interest. OR = Odds ratio. CI = Confidence interval for OR.

Table 2—Pasture-level factors associated with excessive proportions of early fetal losses on horse farms in central Kentucky during 2001

<table>
<thead>
<tr>
<th>Factor</th>
<th>Case pastures (%)</th>
<th>Control pastures (%)</th>
<th>Adjusted OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate or high caterpillar concentration</td>
<td>87.4</td>
<td>40.5</td>
<td>7.1</td>
<td>2.6–19.8</td>
</tr>
<tr>
<td>Pasture primarily contains maiden or barren mares</td>
<td>67.4</td>
<td>27.7</td>
<td>6.5</td>
<td>1.8–23.4</td>
</tr>
</tbody>
</table>

Factors were analyzed by means of multivariable logistic regression with backward elimination. See Table 1 for key.

Table 3—Individual horse-level factors associated with excessive proportions of early fetal losses on horse farms in central Kentucky during 2001

<table>
<thead>
<tr>
<th>Factor</th>
<th>Case mares (%)</th>
<th>Control mares (%)</th>
<th>Adjusted OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bred in February</td>
<td>50.0</td>
<td>10.5</td>
<td>5.4</td>
<td>2.5–12.0</td>
</tr>
<tr>
<td>Exposed to cherry trees in or around pasture</td>
<td>96.1</td>
<td>74.2</td>
<td>7.6</td>
<td>1.1–51.4</td>
</tr>
</tbody>
</table>

Factors were analyzed by means of multivariable logistic regression with backward elimination. See Table 1 for key.
June.10 The strong association between EFLs and cher-
ries from their home tree in pursuit of other food

tures on 1 farm. Caterpillars can travel several hundred
with caterpillars were found within 50 feet of the pas-
maries' pastures. Additionally, crabapple trees infested
later in the summer.10 pear, and peach trees. Caterpillars often defoliate
although caterpillars also nest in crabapple, apple,
ry trees. The only factor that was significantly associat-
ed with excessive EFLs at both the farm and pasture lev-
ell concentrations was distinctive. This was associated
els. It also had 1 of the strongest associations with EFL,
ated with a decreased risk of EFLs was feeding hay to
ry trees during this time in central Kentucky.
The association of farm size with excessive EFLs
likely attributable to the presence of more barren
and maiden mares on these farms. Consequently, a
larger percentage of mares from these farms were bred
during the high-risk time period in February, 2001. A
breeding date in February was highly associated with
excessive EFLs, and maiden and barren mares are the
animals most likely to be bred in this month.

Thoroughbred breeding sheds open in mid-
February, because for registration purposes, all foals
share a January 1 birth date. Therefore, nonpregnant
mares are often bred in February with the expectation
that they will foal early during the subsequent year af-
after a 345-day gestation. Mares bred in February
would have been approximately 60 days pregnant dur-
ing what was considered the time of highest risk for
exposure to factors leading to EFLs and LTAs (April 18
to 28). At approximately 60 days of gestation, the
nutritional source of the fetus is changing from the
choriovitelline placenta to the chorioallantoic placen-
a, a very delicate stage of fetal development.11 This
could possibly help explain why mares bred in
February were at a much higher risk of EFL than mares
bred in late March or early April, which would have
been 28 to 45 days of gestation.

It seems unlikely that larger farms were associated
with higher odds of having excessive numbers of EFLs
simply because more mares were at risk in comparison
to the previous few years. Broodmare populations on
central Kentucky Thoroughbred farms are relatively
consistent from year to year. Most farms maintain
extensive production records for their mares as a mat-
ter of economic necessity, and the farm managers’ esti-
mations of whether EFLs were suffered amounted to
more than speculative recollections. Post-survey data
verification showed that on farms where managers or
owners identified a problem with EFLs, excessive EFLs
occurred regardless of farm size.

The association between frequent exposure of
mares to waterfowl and excessive EFLs was an unusu-
al and unexpected finding. Answers to this question
were categorized as frequent, occasional, and never,
with the interpretation of the latter 2 left to the farm
manager. Follow-up is necessary to determine whether
this finding is spurious or if waterfowl could be an
environmental marker for another cause of MRLS.

Feeding hay to mares outdoors was significantly
associated with a decreased risk of excessive EFLs in
the farm-level analysis but was not significant in the
pasture-level analyses. A possible explanation is that
on the farm-level portion of the survey, the question
asked whether hay was fed outside, whereas on the
pasture-level portion of the survey, the question asked
only whether mares on that particular pasture were fed
supplemental hay (nearly all were). The pasture-level
portion of the questionnaire did not specifically ask
whether the supplemental hay was fed indoors or out-
doors. The farm-level results indicated that feeding hay
outside was protective, while feeding practices in the
barn were not significant. It is possible that mares eat-
ing hay outside were eating less pasture forage in areas
with high concentrations of caterpillars. The feeding of
hay outside was independent of how it was fed,
whether on the ground or in racks or other above-
ground devices. Many farm managers commented that
even though pasture forage was plentiful in April and
May, mares ate hay provided to them outside. This was
unusual in the managers’ experience.

Many managers and veterinarians indicated in
May that mares that had an EFL also had signs of sick-
ness (eg, colic, founder, or vaginal discharge) prior to
aborting. However, in the present study, these findings
were not widespread among the 133 farms investigat-
ed. Farm managers and veterinarians voiced concerns
about the amount of clover in broodmare pastures that
could have been damaged during the mid-April frost;
some types of clover contain cyanogenic compounds,12
and concentrations of these can be higher than normal
in plants under environmental stress, such as drought
or temperature extremes. The percentage of clover in
pastures and the percentage of clover combined with
mowing practices before, during, and after the April
frosts were scrutinized in the analyses, but there were
no significant differences between affected and control
pastures. The list of management factors not associat-
ed with excessive EFLs was of great value to farm man-
agers who were at a loss as to how to manage pastures
and grazing times for their horses. This was why many
factors of concern brought forward from the industry
at multiple informational meetings during May 2001
were included in the questionnaire.

One strength of this study was the rapidity with
which it was designed, implemented, analyzed, and
reported. Few other large equine emergency epidemiology studies have been reported.\textsuperscript{1,11} In the face of an emerging threat to the horse industry, \texttextless; 120 farm visits were conducted by the investigators and a team of volunteers in just 1 week. Data collection during June 2001 also helped minimize memory bias, as data were collected within 1 month of the peak number of EFLs. Less than 2 months after initiation of the survey, a summary of preliminary results was released. Final results were summarized for the industry approximately 2 months later.

All of the work reported in the present study was performed concurrently with other activities investigating the cause of MRLS throughout the region. On-site administration of the questionnaire was used to ensure timely return of the data, allow explanation of questions with farm managers, and clarify responses for unusual circumstances. This also allowed data collectors to observe the farm and evaluate some variables with farm managers as data were collected. For example, the presence of wild cherry trees, which not all managers were able to identify, was often evaluated by data collectors working with the farm managers. Photographs were also taken by the data collectors to maintain a visual record of the pastures in case they were needed later.

Some of the limitations of this study were related to the urgency of finding a solution to this outbreak. The choice of using farm managers’ perceptions that EFLs were in excess of those during the past few years as a qualitative outcome was made to allow more farms to be included in the study and to expedite data collection. More quantitative approaches, such as using a cutoff for the number of EFLs that would be considered excessive (eg, a \texttimes{} 20\% or \texttimes{} 30\% increase compared with previous years), were investigated and not found to have an advantage, considering the wide range in farm size. In retrospect, the approach reported here seems to have worked well. Farms identified by managers as having excessive numbers of EFLs had 36\% of mares previously confirmed to be pregnant that were no longer pregnant after \geq{} 60 days of gestation, compared with 9\% of mares on control farms.

Given the large amount of publicity surrounding this outbreak, the many theories on possible causes of the problem, and the work being done to address the problem, it is possible that some of the more subjective observations in the data were susceptible to bias. Information bias caused by differential recall is difficult (if not impossible) to eliminate in this type of retrospective study. However, because there were many theories circulating at the time, it seems unlikely that the net effect of this bias for any given variable would have resulted in odds ratios of the magnitude reported here. Also, recall bias has less potential effect on easier to recall observations (eg, massive numbers or blankets of caterpillars covering fences and water buckets) than on harder to remember observations (eg, how much clover was present in a pasture several weeks ago).

Areas for further investigation identified in the present study include determining whether the pathogenesis of MRLS is related to caterpillars, cherry trees, feeding hay, or the presence of waterfowl as causal factors or whether these are markers for other causal factors. Because of the geographic distribution and multiple breeds involved, the inability to identify a primary infectious agent after exhaustive efforts, and the unusual environmental factors that were present in April 2001, researchers recognize that a complex disease led to the reproductive losses associated with MRLS. Additional experimental and observational studies will be needed to clearly identify the causes of MRLS.

In an economic impact survey completed at the University of Louisville in September 2001, the cost of MRLS to the Kentucky equine industry from 2000 to 2003 was estimated to be \text{}336 million.\textsuperscript{12} With this tremendous impact on the horse industry in Kentucky alone, investigations and prospective studies that are underway will continue until the etiology of this costly and complex disease is understood.

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\textsuperscript{1}Harrison L, Livestock Disease Diagnostic Laboratory, University of Kentucky, Lexington, Ky: Personal communication, 2001.
\textsuperscript{3}Riddle T, Rood and Riddle Equine Hospital, Lexington, Ky: Personal communication, 2001.
\textsuperscript{4}McDowell K, Gluck Equine Research Center, University of Kentucky, Lexington, Ky: Personal communication, 2001.
\textsuperscript{5}Epi-Info version 6.0, Centers for Disease Control and Prevention, Atlanta, Ga.
\textsuperscript{6}PROC FREQ, SAS/STAT version 8.2, SAS Institute Inc, Cary, NC.
\textsuperscript{7}Microsoft Excel 97, Microsoft Corp, Redmond, Wash.
\textsuperscript{8}PROC RLOGIST, SUDAAN release 5.50, Research Triangle Institute, Research Triangle Park, NC.
\textsuperscript{9}PROC LOGISTIC, SAS/STAT version 8.2, SAS Institute Inc, Cary, NC.

The following individuals assisted in the development of the questionnaire used in this study: Drs. Bob Coleman, Barry Fitzgerald, Ralph d’Arge, Barry Meade, Michael Pavlick, and Karen McDowell. Data collectors from the Kentucky USDA offices included Amy Applegate, Richard Broadwater, Garry Cracraft, Grace Halmhuber, Roger Murphy, Mitch Netherly, and Dr. Michael Pavlick. Data collectors from the Kentucky State Veterinarian’s Office included Ron Craig, Tammy Cobb, Dr. Ed Hall, Dennis Hasty, Shane Mitchell, Mike Tobin, and Dr. Chris Young. Volunteer data collectors included Robert Holley, Catherine Wagner, and Drs. Atwood Asbury, James Bowen, Jessica Hoane, David Powell, DL Proctor Sr, H Sutton Sr, and Melissa Newman.

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References


