Gait and speed as exercise components of risk factors associated with onset of fatigue injury of the third metacarpal bone in 2-year-old Thoroughbred racehorses

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Objective—To determine the degree to which components of the training program of 2-year-old Thoroughbred racehorses influence their susceptibility to fatigue injury of the third metacarpal bone (bucked shins).

Animals—226 two-year-old Thoroughbred racehorses.

Procedure—Daily training information and health reports on 2-year-old Thoroughbreds were compiled from records provided from 5 commercial stables. For each horse, data (exercise variables) were collected that comprised distance jogged (approx speed of 5 m/s), galloped (approx 11 m/s), and breezed (approx 15 to 16 m/s) until a single instance of bucked shins was reported. Data were coded for analysis using cross-tabulation, graphic, and survival techniques.

Results—Of 226 horses, 56 had bucked shins, 9 completed the observation period without bucked shins, and 161 were lost to follow-up. Distinct training strategies were used at stables resulting in significantly different survival profiles among stables. Mean (± SD) allocation of exercise to breezing was 0.15 ± 0.13 miles/wk (maximum, 0.64 miles/wk), to galloping was 4.47 ± 1.52 miles/wk (maximum, 9.56 miles/wk), and to jogging was 2.34 ± 1.70 miles/wk (maximum, 8.53 miles/wk). Survival (ie, lack of bucked shins during 1 year of monitoring) was found to be significantly reduced by exercise allocation to breezing, significantly increased by exercise allocation to galloping, and uninfluenced by exercise allocation to jogging. The log of the hazard ratio was reduced by 4.2 ± 1.5/mile breezed and increased by 0.3 ± 0.1/mile galloped.

Conclusions and Clinical Relevance—Relationships between different gaits and speeds in the training regimen influence the incidence of bucked shins. To reduce the incidence of bucked shins, trainers should consider allocating more training effort to regular short-distance breezing and less to long-distance galloping. (Am J Vet Res 2000;61:602–608)

The cause of periostitis of the dorsal surface of the third metacarpal bone (bucked shins) has become clearer through a series of field and laboratory investigations. Thoroughbreds are more susceptible to the disease than Standardbreds' and 2-year-old Thoroughbreds are more at risk than older Thoroughbreds. Furthermore, evidence exists from bone morphologic research and from reported field observations that training method, or exercise paradigm, influences bone formation and susceptibility to bucked shins. Racetrack surface has also been investigated in relation to this disease. Results of work by Moyer et al indicate that track surface could be related to the incidence of bucked shins. Unfortunately, this particular conclusion was confounded by the training paradigm. To our knowledge, direct attempts to analytically relate training paradigm to the onset of bucked shins in 2-year-old Thoroughbreds or to separate the potential confounding effect of training surface on the exercise effect have not been done.

Results in a number of reports illustrate the application of statistical techniques to the analysis of racehorse related data. Mohammed et al, in a series of papers on external risk factors associated with injuries in Thoroughbred racehorses, used logistic modeling to derive odds ratios of breakdown in conjunction with such putative risk factors. Kane et al used similar statistical modeling approaches in their exploration of horseshoe characteristics as possible risk factors for musculoskeletal injury of Thoroughbred racehorses. A technique that, although appropriate, has not been used in the analysis of longitudinal studies on 2-year-old racehorses is survival analysis. With this technique, using probabilistic modeling in a manner similar to that of logistic modeling, the investigator attempts to relate risk factors to failure rate in an effort to develop a model best describing the propensity for animal survival in regard to the disease of interest. Grohn et al described these techniques in an investigation of mastitis in regard to culling in dairy cattle. This article is particularly helpful because it overviews strategies when the underlying assumptions of straightforward survival analysis are not met.

The purpose of the study presented here was to describe the application of survival analysis to modeling bucked shin events as reported by trainers in training records for 2-year-old Thoroughbreds. Our goal was to explore the nature in which training paradigm was implicated in these events.

Materials and Methods

Animals—Two hundred and twenty-six 2-year-old Thoroughbred racehorses from 5 stables in the Eastern United States were included in this study. Participants were

Received Nov 23, 1998.
Accepted Dec 2, 1999.
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Supported by the Grayson-Jockey Club Research Foundation Inc, NIH RO1 AR40393-03.
The authors thank Jennifer Armstrong, Jodi Barton, and Lon Leming for technical assistance.
selected on the basis of their knowledge or interest in work at New Bolton Center on racehorse training. The motivation for participation was to assist in understanding risk-related training factors. For each stable, the only requirement was that entire training programs and health records of 2-year-old Thoroughbred racehorses were made available.

All horses that entered the study were 2-year-old Thoroughbreds. Although able to be ridden, horses began their training for racing as they entered the study. Horses were first trained by being able to be ridden, able to start breezing until they were fit and able to gallop a mile (18 second furlongs [11.176 m/s]) comfortably. Horses were not permitted to start breezing until they were fit and able to gallop a mile comfortably. Horses were then assigned to their training for racing as they entered the study. Horses of 2-year-old Thoroughbreds. Although able to be ridden, horses began their training for racing as they entered the study. Horses were first trained by being able to be ridden, able to start breezing until they were fit and able to gallop a mile (18 second furlongs [11.176 m/s]) comfortably. Horses were not permitted to start breezing until they were fit and able to gallop a mile comfortably. Horses were then assigned to their training for racing as they entered the study. Horses were first trained by being able to be ridden, able to start breezing until they were fit and able to gallop a mile (18 second furlongs [11.176 m/s]) comfortably.

Table 1—No. of 2-year-old Thoroughbreds followed in the study by year and stable

<table>
<thead>
<tr>
<th>Year</th>
<th>Stable 1</th>
<th>Stable 2</th>
<th>Stable 3</th>
<th>Stable 4</th>
<th>Stable 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>10</td>
<td>12</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>39</td>
</tr>
<tr>
<td>1982</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>1983</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>1984</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>1991</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>1992</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>1993</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>1994</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>1995</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>1996</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>1997</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>25</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>62</td>
</tr>
</tbody>
</table>

Data collection—For 3 stables accessible from New Bolton Center (stables 1 to 3), visits were made on a monthly basis, and daily training information for each 2-year-old Thoroughbred was copied directly onto coding sheets for computer entry. Remote stables sent copies of similar training information for computer recording. Information available from each training stable included details of distance allocation to each training component (breezing [approx speed of 15 to 16 m/s], galloping [approx 11 m/s], and jogging [approx 5 m/s]) in addition to health status reports. In regard to health reports, special care was taken to follow-up details of any training suspension of a racehorse or a report of bucked shins. All daily data were entered into a spreadsheet file for validation and processing preparation.

Data analysis—Because the prime concern of this investigation was training factors associated with the onset of bucked shins in 2-year-old Thoroughbred racehorses, a single occurrence of bucked shins (event) in a racehorse was isolated as a point at which following the horse ceased. One hundred and sixty-one racehorses left the stables during their first year of training period (lost to follow-up), and at that stage collection of information was also discontinued. Each 2-year-old racehorse was coded as a single record in the final data file for statistical analysis. Data recorded included the following: status (ie, 1 if the horse had bucked shins, and 0 if the horse completed the year without bucked shins or was lost to follow-up, such a variable in survival analysis is routinely referred to as a censoring variable), exit time (ie, time in days until either bucked shins, or being lost to follow-up, or completion of the year without bucked shins), mean exercise rates (ie, miles/wk of breezing, galloping, and jogging), cumulative exercise (ie, total miles of breezing, galloping, and jogging), and health events (ie, coded representation of health reports other than bucked shins).

Analyses were done using statistical software. Tabulate, ANOVA, nonparametric, and survival-time utilities were used as follows: (1) validate the data by summary and range checking; 2) tabulate the data to obtain an overview of data distribution among classes and to check general associations among category variables; 3) examine the pattern of training programs among stables, using nonparametric methods; 4) examine the survival pattern of racehorses among the stables to establish the existence of a difference between stables using the log rank and Wilcoxon tests; 5) model the potential relationship of bucked shins onset and training pattern using survival analysis on the basis of the data from all stables (Cox and Weibull8-10 regression assisted in the isolation of the nature and importance of the role of training components with the onset of bucked shins); 6) perform statistical checks to ensure that the assumptions surrounding the application of Cox regression (proportional hazards) to data had not been violated11; and, 7) repeat the analysis limiting the data set to 2 stables (stables 1 and 2) that trained horses on the same surface, thus, removing the potentially confounding influence of track surface.

Commonly, medical outcomes are modeled, using variations of logistic regression. A probability model for outcome (eg, binomial for ordered processes or negative binomial for clustered or over-dispersed processes) is developed and an attempt is made to locate clinical and other factors that can be combined to describe the changing pattern of the probability model variables between sub-groups of data.12 The actual process of locating important factors amounts to exploring the degree to which alternate combinations of factors improves the likelihood that the model (probability and covariate model together) could have given rise to the observed data.

Work by Greene indicates that for rare diseases followed briefly, results between survival analysis and logistic (outcome) modeling are similar.13 However, generally (largely because of extensions to survival analysis) when time to outcome observations are available, more power is derived from modeling the data using survival techniques than using logistic approaches. The principle behind survival analysis, although mechanically similar, has subtle differences from logistic modeling.

Using survival analysis, it is assumed that the rate of change of the surviving set can be written in the following form:

$$S(t) = -h(t)\cdot S(t)$$

where S(t) (ie, the survivor function) is the probability of surviving beyond time t, and h(t) (ie, the hazard function) is the failure rate. Interestingly, survival analysis focuses on h rather than S. The objective of the investigation is to explore internal and external factors influencing the value of h for a particular individual (ie, in our study, horse) as follows:

$$h(x,t) = h_0(t) \cdot L(x)$$

asserting that h(x,t) can be separated into a time-dependent part (the baseline hazard function) and a non-time-depen-
Table 3—Mean (± SD) pattern of exercise at the 5 stables

<table>
<thead>
<tr>
<th>Stable No.</th>
<th>Jog rate* (miles/wk)</th>
<th>Gallop rate† (miles/wk)</th>
<th>Breeze rate‡ (miles/wk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.031 ± 0.898</td>
<td>5.360 ± 1.831</td>
<td>0.132 ± 0.076</td>
</tr>
<tr>
<td>2</td>
<td>1.013 ± 0.937</td>
<td>3.869 ± 1.013</td>
<td>0.311 ± 0.148</td>
</tr>
<tr>
<td>3</td>
<td>1.388 ± 0.461</td>
<td>4.309 ± 1.165</td>
<td>0.083 ± 0.059</td>
</tr>
<tr>
<td>4</td>
<td>3.513 ± 0.352</td>
<td>5.861 ± 1.112</td>
<td>0.152 ± 0.096</td>
</tr>
<tr>
<td>5</td>
<td>6.041 ± 1.083</td>
<td>2.820 ± 1.028</td>
<td>0.099 ± 0.098</td>
</tr>
</tbody>
</table>

*Jog rate = A speed of approx of 5 m/s. †Gallop rate = A speed of approx 11 m/s. ‡Breeze rate = A speed of approx 15 to 16 m/s.

Results

Of 226 racehorses, 56 had bucked shins, 9 completed their year of training without bucked shins, and 161 were lost to follow-up (Table 2). Time at risk was the cumulative number of exposure days for each stable, and incidence rate was the number of failures divided by the time at risk. Similar incidence rates existed for stables 1 and 4 (P = 0.55), and for stables 3 and 5 (P = 0.67). Stable 2 had a substantially lower incidence rate than either of these pairs, although only the difference in incidence rate between the first pair, 1 and 4, and the other stables was significant (P = 0.005). In each case, incidence rate differences were examined using Poisson regression14,13 in conjunction with specially refined indicator variables for the appropriate contrast. Hypothesis tests were conducted with the aid of the likelihood ratio test. The overall incidence rate was 1.47 failures/1,000 training days.

Stables 1 and 4 had similar mean breeze, gallop, and jog rates (ie, miles/wk; Table 3). Stables 3 and 5 had similar breeze rates. Stable 2 had a unique training pattern clearly favoring breezing at the expense of either galloping or jogging.

Because of observed non-normality and heteroskedasticity, differences of exercise components (breezing, galloping, and jogging exercise rates) amongst stables were explored using the Kruskal-Wallis test.14 Breeze rates and gallop rates were found not to differ (P = 0.40) between stables 1 and 4, and breeze rates were the same (P = 0.85) between stables 3 and 5.

The survival pattern among stables (including those horses without bucked shins and not being lost to follow-up) indicated that horses without bucked shins remained in the risk set a mean of 25 days longer than those having bucked shins; however, considerable variability between stables was found (Table 4). Stable 2 had the longest mean survival time (170 days) for horses with bucked shins, whereas stable 1 retained horses that did not have bucked shins in the training program for the longest time (253 days) before being lost to follow-up. Stable 5 had the shortest mean survival time (127 days) for horses that had bucked shins and stable 3 had the shortest mean time (128 days) in the program for horses lost to follow-up.

Comparing the pattern of exercise at stables with outcome, mean gallop rate and mean jog rate were higher for horses with bucked shins, compared with horses without bucked shins, whereas mean breeze...
rate was lower for horses with bucked shins, compared with horses without bucked shins (Table 5). Results of directional hypothesis tests, allowing for variance heterogeneity, were not significant for breeze and jog rates ($P = 0.10$), but were significant for gallop rate ($P = 0.018$). This mean pattern was replicated in stable 1, partially replicated in stables 2, 4, and 5, but was entirely reversed for stable 3. Stables 2 and 5 had similar patterns.

The Kaplan-Meier survival plots to Fig 1 for all stables were determined as well as survival by stable. A steady pattern of failure from day 22 to 328 with the greatest failure between days 150 and 175 was observed. Mean time that horses lost to follow-up were in the risk set exceeded the mean time that horses with bucked shins were in the risk set. A higher failure rate for stable 1 was found, compared with stable 2. Survival patterns between stables 3 and 5 were similar. Survival patterns between stables 1 and 4 were also similar, and, conversely, survival patterns for stables 1 and 4 were dissimilar, compared with stable 2.

A log rank test to establish the overall association between survival and stable yielded a significant difference between stables ($P = 0.049$). To remove the chance of ties influencing judgment of an association, the association using the Breslow generalized Wilcoxon test to correct ties was also tested ($P = 0.028$). Tied data refers to the simultaneous occurrence of observations; that is, 2 or more horses being censored or developing bucked shins on the same day.

To explore the association of training component on survival, stratified and unstratified Cox regressions, using robust regression techniques for error estimation were performed. Here stratification was with respect to stable.

The result of the unstratified analysis indicated that the overall relationship between the survival and training component model was significant ($P = 0.001$).
However, although breeze rate via its coefficient in the survival model and the error estimate for the coefficient was significantly protective against bucked shins, galloping had the reverse effect. Jogging had no direct effect on survival. When jogging (ie, jog rate) was dropped from the model, alterations to the remaining coefficients were minimal. On the basis of these findings, the log of the hazard ratio decreased by 4.2/mile breezed/wk (ie, 0.53/furlong breezed/wk), and increased by 0.28/mile galloped/wk.

It is not uncommon to use exponentiation of survival model coefficients and describe the associate risk factor effect in a multiplicative fashion. This resulted in a 33% increase in the hazard ratio with each additional mile galloped/wk (ie, 0.33/furlong galloped/wk), and increased by 0.28/mile galloped/wk.

Assumptions of Cox regression were 1) an approximate preservation of the temporal survival pattern across stables, and 2) an approximate constancy of survival with time. To test assumption 1, a stratified Cox regression was performed, using stables as strata. Each stratum (stable) had its own baseline hazard function and a single time-independent hazard model was imposed across strata. Overall changes in model significance was looked for as well as changes in the significance level and covariate coefficient values in the hazard function if the assumption of preservation of the temporal pattern was violated. A significant change in the overall goodness of the model was not found, and none of the coefficients were significantly altered.

Assumptions 2 was more difficult to test as a result of some evidence of time dependence of the survivor function in the latter half of the study. That is, a log-log plot of S(t) against log time revealed a degree of departure from linearity in the second half of the year. To explore this, a time-varying covariate function of jogging, breezing, and galloping was created in which, in addition to the base, or nontime dependency of survival on these covariates, there was admitted a time dependency on them in the period where the proportional hazards assumption appeared questionable. Neither breezing nor galloping when introduced in the time-dependent form led to identifiable accelerated survival dependencies (P = 0.75), however, there was a suggestion of a time-dependent jogging effect (P = 0.041).

To quantify the mean temporal pattern of failure of horses, the survival pattern using a Weibull model was additionally examined. Averaged over all stables, the hazard function increased at the rate of time^{1.35}, (the exponent, 1.35, was observed by subtracting 1 from the P value). The complete hazard function is as follows:

\[ h(j, g, b, \text{time}) = 2.4 \text{time}^{1.35} \exp(-14.6 + 0.027 j + 0.33 g - 4.9 b) \]

where j, g, and b refer to jog, breeze, and gallop rates (miles/wk), respectively.

Jogging can be dropped from this model without affecting the coefficients of the other covariates. The Weibull-based coefficients were not significantly different from the ones derived earlier from the Cox regression.

The relationship between survival and exercise components when training on a common surface was explored. Stables 1 and 2 were located at the same track and, thus, an analysis involving only stables 1 and 2 served to at least partially remove the effect of track surface. Analysis resulted in a Cox model that was significant overall. The pattern of influence, and level of significance of gallop and breeze rates were consistent (albeit somewhat amplified), compared with using data from all stables. Jog rate, again, had no influence on survival.

**Discussion**

This investigation was conducted to establish the role of exercise in the survival pattern in 2-year-old Thoroughbred racehorses with regard to bucked shins. Although results of one field study reveal that there are relationships between bucked shins and age, breed, or even some training methods, to our knowledge, there has not been a study to determine the relationships between different exercise patterns in commercial racehorse training populations and the incidence of bucked shins.

Results of another study from our laboratory indicate that different exercise patterns develop different

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**Table 5**—Mean breeze, gallop, and jog rates (miles/wk) among horses that had bucked shins (event = 1) and did not have bucked shins (event = 0) by participating stables

<table>
<thead>
<tr>
<th>Stable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeze (miles/wk)</td>
<td>0</td>
<td>0.13</td>
<td>0.33</td>
<td>0.08</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>1</td>
<td>0.13</td>
<td>0.22</td>
<td>0.09</td>
<td>0.15</td>
<td>0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>Mean</td>
<td>0.13</td>
<td>0.31</td>
<td>0.08</td>
<td>0.15</td>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>Gallop (miles/wk)</td>
<td>0</td>
<td>4.64</td>
<td>3.99</td>
<td>4.39</td>
<td>5.58</td>
<td>5.88</td>
</tr>
<tr>
<td>1</td>
<td>6.29</td>
<td>3.31</td>
<td>3.86</td>
<td>6.22</td>
<td>2.11</td>
<td>4.97</td>
</tr>
<tr>
<td>Mean</td>
<td>5.36</td>
<td>3.87</td>
<td>4.31</td>
<td>5.86</td>
<td>2.82</td>
<td>4.47</td>
</tr>
<tr>
<td>Jog (miles/wk)</td>
<td>0</td>
<td>2.82</td>
<td>1.07</td>
<td>1.42</td>
<td>3.40</td>
<td>6.23</td>
</tr>
<tr>
<td>1</td>
<td>3.31</td>
<td>0.77</td>
<td>1.19</td>
<td>3.66</td>
<td>5.18</td>
<td>2.67</td>
</tr>
<tr>
<td>Mean</td>
<td>3.03</td>
<td>1.01</td>
<td>1.39</td>
<td>3.51</td>
<td>6.04</td>
<td>2.34</td>
</tr>
</tbody>
</table>
loads and bending forces in the equine third metacarpal bone. Slow galloping may lead to tension on the dorsal surface of this bone, whereas breezing will result in compression on this surface. Our hypothesis was that bone models and remodels on the basis of the loads it receives (Wolff's Law). Horses that train in a mode that resembles slow-speed galloping will acquire bone that is adapted to that training modality and will be susceptible to bucked shins. If the training pattern resembles racing, then the bone will become adapted to racing without the horse developing bucked shins. The introduction of short periods of breezing at the end of 1 mile gallops 2 to 3 times a week was tried in another study as a measure to reduce the incidence of bucked shins by changing bone structure. Bone structure changed substantially, but the decreased incidence of bucked shins from such a program, although noteworthy, was anecdotal on the basis of the number of horses in the study. In our study reported here, stable 2 used this method to train its horses. Stable 5 was also aware of the method and used it to some extent. Stables 1, 3, and 4 did not try to follow this regimen and trained horses in a classical manner. Classical training refers to the usual regimen of galloping horses 1 to 1.5 miles/d and breezing every 7 to 10 days. The breeze distances may be up to 0.5 miles or even more.

We had drawn from retrospective and prospective training records using 5 stables training horses for more than 11 consecutive years to compile the data for this investigation. Data sets from stables training on the same surface were coupled to control for this factor as a potential confounder in our investigation. Our essential finding was that training programs that focused on breezing had substantially better survival profiles than those that focused on galloping. Indeed, breezing was found to be a protective component of training, whereas excessive galloping placed the horse at risk. Jogging had no consistent influence on survival. This does not mean that unlimited breezing would be protective. Results of one study indicate that long distances of high-speed exercise increases the risk of fatal breakdown injuries in Thoroughbred racehorses. The control group (safe group) in that study breezed or raced up to 25 furlongs in a 2 month period. The horses in the highest breeze group (stable 2) in our current study breezed < 20 furlongs in this same period. Results of our study indicate that there is a protective nature of breezing when used within the context of the distances reported here. Optimization of the training schedule has not yet been attempted, but results of our study indicate that protective attributes associated with the incorporation of breezing in the early training of Thoroughbred racehorses decreases the incidence of bucked shins.

It was not surprising that the data bore consistency across the entire study in regard to the role of exercise components on survival. The only distorting issue here was whether the data quality changed between the retrospective and prospective phases. However, one pervasive feature of the racehorse training industry is the attention trainers give, and had routinely given, to accurate recording of training information (daily time spent by each horse in the various exercise modes), and because our investigation was purely record based, its reliability across time was perceived to be stable. As a condition of our analysis, it was asserted that training patterns were uniform over time (ie, within a year the approach to training did not vary significantly; or that the rate of exercise application was on the basis of more or less the same pattern within a year). Two points can be made in defense of this assumption. First, it would be difficult for trainers to judge the consequence of training pattern changes if they were applied during a year. They would have no reference by which to assess the impact. The standard approach (ie, under normal conditions) is to only make adjustments to an entire year's training program and then, over time, explore the consequences. Second, our data retrieval and analysis means were structured in such a way that any consequences of yearly training shifts in regard to our outcome of interest could be appropriately ascribed. That is, an unfavorable training maneuver (one that increases the incidence rate) would have been detected, and the increased risk assigned to the feature of the training change most strongly associated with the increase in events.

A key issue at the heart of any epidemiologic study is that of generalization. In our study the issue is how reflective are the study's stables of racehorse training programs to stables at large. The 5 stables participating in our study came from 4 states and ranged in size from a year maximum of 82 horses to a year minimum of 2 horses. They used diverse training programs ranging from pure classical approaches to modifications to the classical approach and from their operational prospective, they retained their 2-year-old Thoroughbreds for various durations.

References


Book Review:

The authors have done an admirable job of delivering in an economical and condensed format the salient information that a laboratory animal program manager or veterinarian needs to provide quality care of sheep and goats in the research environment. The authors comprehensively cover biology, husbandry, management, veterinary care, experimental methods, and provide a helpful list of print and electronic resources available for more in-depth information. Of particular interest is the discussion of providing environmental enrichment for these social species and a relevant emphasis on occupational health issues. The authors are careful to delineate the husbandry and veterinary care issues that are unique to the laboratory setting in comparison with common farm practices. The writing style, topics covered, and amount of detail provided makes this book suitable for beginning laboratory animal science professionals as well as serving as good reminder of basic veterinary protocols to more experienced staff. The only distractions to this book are several typographic errors. This book is a good addition to the laboratory animal science library and will be an excellent resource for everyone who manages sheep and goats in the laboratory.

Mark T. Whary, DVM, PhD