A FARM-BASED PROSPECTIVE STUDY FOR EQUINE COLIC RISK FACTORS AND RISK ASSOCIATED EVENTS

by

Mary Kay Tinker

Dissertation submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

IN

VETERINARY MEDICAL SCIENCES

APPROVED:

Kevin D. Pelzer, Chairman

Pierre Lessard, Co-Chairman

Nathaniel A. White

Craig D. Thatcher

Lorin Warnick

Suzanne Jenkins

August 1995

Blacksburg, Virginia

Key words: Epidemiology, Logistic-Regression, Follow-up Study, Management, Nutrition,

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(ABSTRACT)

Improved definition of risk factors for equine colic is necessary to develop effective interventions to reduce colic incidence. A one-year prospective study was conducted to estimate colic incidence and to identify risk factors. Farms with greater than 20 horses were randomly selected from two adjacent counties of Virginia and Maryland. Management information was recorded by questionnaire for 31 farms with 1427 horses. Owners kept calendars to record occurrence of specified events. Colic was reported by the owner when a horse exhibited signs of abdominal pain.

The incidence of colic was 10.6 colic cases per 100 horse-years, based on 104 cases per 983.5 horse-years. Twenty-five deaths occurred from all causes, the proportional mortality rate of colic was 7/25 (28%).

Risk factors were analyzed by logistic regression at the farm-level and the horse-level with farm as a random effects variable. No farm-level variables were significant. Significant horse variables were: age 2-10 years, odds ratio (OR)=2.8 (95% confidence interval, 1.2-6.5); previous colic, OR=3.6(1.9-6.8); changes in concentrate feeding during the year, OR=3.6(1.6-5.4); more than one change in hay

feeding during the year, OR=2.1(1.2-3.8); feeding high levels of concentrate (>2.5 kg/day dry matter, OR=4.8(1.4-16), >5 kg/day dry matter, OR=6.3(1.8-22)); and vaccination with monocytic ehrlichiosis vaccine during the study, OR=2.0(1.8-22). Feeding whole grain with or without other concentrates had less risk than diets without whole grain included. Variables related to concentrate feeding frequency or concentrate type could be substituted for the concentrate level variable.

A nested analysis examined risk for the time period following an event. The odds ratio was determined for the proportion of cases with an event within 14 days prior to the colic-date, relative to the proportion of horses without colic with an event within 14 days of a date chosen at random from the observation time. Weather events were analyzed for the three days before the colic or assigned date. Foaling was analyzed for three time periods: before, 0-60 and 60-150 days post-foaling. Significant events were recent vaccination, OR=3.31(1.9-6.0); recent transport, OR=3.3(1.2-5.5); 60-150 days post-foaling, OR=5.9(1.8-13); and recent fever, OR=20(2.5-169). Snow on the day of the colic, OR=2.8(1.0-7) and humidity <50% the day before the colic OR=1.6(1.0-2.9) were marginally significant.

Acknowledgements

I am the sole person responsible for the writing of this dissertation, the analysis of the data and the interpretation of the results. The Equine Colic Project was the collaboration of researchers from the three campuses of the Virginia-Maryland Regional College of Veterinary Medicine: Virginia Tech, Blacksburg, Virginia; the Equine Medical Center, Leesburg, Virginia; and the University of Maryland, College Park, Maryland. The collaborating investigators were Nathaniel A. White, Pierre Lessard, Craig D. Thatcher, Kevin D. Pelzer, Betty Davis, Doug K. Carmel and myself. The research was supported by a grant from the American Quarter Horse Association with additional support from the Equine Research Fund of the Equine Medical Center, Leesburg, Virginia. I thank the other investigators for giving me the opportunity to learn from such a wonderful project.

I want to thank the Virginia-Maryland Regional College of Veterinary Medicine for my graduate assistantship support that provided me an opportunity to continue my education. I am also grateful to the Vaughan family and the Pauline Willson-Gunn family for scholarship support I received.

This is a large study with 31 farms, 1427 horses and megabytes of data. The study design was developed and the project initiated before I began as a graduate student. Data collection began November 1990 and I joined the project soon after in January 1991. The 31 study farms are in Loudoun County, Virginia and Montgomery County, Maryland. The owners and managers of the farms made this study possible. Their vigilance in reporting the colic episodes and recording the required information was essential for the study validity. With their thorough and continuous cooperation, I had good information to analyze. Dr. White coordinated the data collection from the Equine Medical Center which is in Loudoun County. Betty Davis was the project technician who handled the majority of the farm contacts, following up on the colic reports, making the quarterly visits to the farms, updating horse-lists, collecting calendars, and taking feed samples. The research team helped with the initial questionnaires, and the collection of fecal and pasture samples. I set up the data management structures, but Betty spent days entering a large part of the data. She personally knew all the farms and was extremely important in working with the horse owners. Veterinary students, now graduated, Jane Rooney and Jeri-Lyn Snyder also helped with the data entry. Susan King, under the direction of Dr. Anne Zajac, performed the parasitology tests on the fecal samples. Ralph Roop took charge of submitting the feed samples to the Forage Testing laboratory and entering the results into the computer.

I thank Dr. Pierre Lessard for being my original advisor, setting an example of an analytical epidemiologist, and always being a strong supporter. I thank Dr. Kevin Pelzer for taking over when Pierre left for Kenya and seeing me through my preliminary exam and dissertation writing. Kevin was good at asking a question that made me work to clarify my thinking and writing. I thank Dr. Nat White for helping me while I struggled to organize, analyze and write about this mass of data.

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Most of all I want to thank my family, my husband Nick, and children, Joanna, Benjamin, Andrew, and Jack for their love and understanding through the ups and downs of the last four years. They have helped and sacrificed to provide me time to work. Our family purchased a home computer, but no one has gotten much chance to use it because Mom was always working on it. As soon as baby Andrew could crawl up into the chair, he started adding some interesting text and spaces to my papers. He learned quickly that keyboards make noises that bring Mommy running.

I found this project to be intellectually stimulating and a great opportunity from which to learn. I am grateful to my colleagues at the Virginia-Maryland Regional College of Veterinary Medicine graduate school for helping lay the foundation for my future growth and learning in epidemiology and veterinary medicine. The professors and my colleagues provided an environment for my learning and development as a scientist. As I look forward to new challenges in my career I will use what I have received here and do my best to impart it to others.

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List of Abbreviations

ANOVA=Analysis of Variance

CI=Confidence Interval

Conc=Concentrate

EIA=Equine Infectious Anemia

EWE=Encephalomyelitis Combination Vaccine

FLU=Influenza Vaccine

FT=Fulltime

HL=Hosmer-Lemeshow test

ID=Incidence Density

IDR= Incidence Density Ratio

KW=Kruskal-Wallis test

LR=Logistic Regression

MMC=Migrating Myoelectric Complex

NRC=National Research Council

OR=Odds Ratio

PHF=Potomac Horse Fever (monocytic ehrlichiosis)

PT=Parttime

RAB=Rabies Vaccine

RHINO=Rhinopneumonitis Vaccine

RR=Risk Ratio

%SCL=Scale term for random effects logistic regression

STD ERROR=Standard Error

STR=Strangles Vaccine

TET=Tetanus Vaccine

Chapter 1

Introduction

Prevention of equine colic is a goal that requires a clear understanding of the causes and mechanisms that lead to the disease. Veterinarians recommend parasite control, sound nutrition, adequate water, regular dental care, removal of foreign materials from the environment, and gradual changes in feeds and exercise to prevent colic[1]. The guidelines are basic and general, promoting good health and prevention of many diseases. However, colic occurs in horses in which preventive measures appear to be followed. Elimination of parasites through effective anthelmintic agents and environmental management has been the major focus of previous work. Scientific study to document other specific preventive measures for colic are lacking.

Studies of colic have several inherent problems because of the broad "disease" definition. Colic is defined as acute abdominal pain[2], which may be due to many types of lesions[3]. In mild cases, those receiving no or only medical treatment, the actual lesion is usually unknown. Investigators must make a choice between studying all colics or a subset of cases where the lesions have been definitively identified by surgery, necropsy or clear-cut clinical signs. The first choice means working with multiple lesions, some of which may not be closely related. The second choice means limiting the study population to a small number of serious cases. The choice is dependent upon the study goals. All colics were used for this study based on the assumption that for most colic the end pathological result is not specific to the cause. The cause or causes are hypothesized to initiate a gastrointestinal or abdominal abnormality that leads to further aberrations in motility, circulation, position, digestion or inflammatory response that manifest in pain. Sometimes the abnormality may progress to a serious lesion such as a strangulation or obstruction, depending on other horse factors. One causal factor may be involved in the initiation of multiple types of colic pathology and one type of colic pathology may have multiple causes. If this hypothesis is accepted then working with a group of cases selected by pathology does not help clarify cause and effect relationships.

Literature concerning the causality of colic should be evaluated based on the strength of evidence supporting a possible mechanism. Reports on causal factors can be divided into four types: 1) risk factors mentioned by authors without reference to any data, 2) risk factors that come from case reports and series without a control population comparison, 3) risk factors where a comparison has been made with a control population, and 4) experimentally tested risk factors. The first type are anecdotal or based on the author's experience or accepted knowledge from textbooks or other experts. The second type includes reports of abnormal findings that were documented in association with colic lesions. While cause is not directly linked to effect, if abnormalities are rare findings in horses without colic and the role of the abnormality in the colic is plausible biologically, then abnormalities are likely causes. For example, large amounts of hair in the intestine would generally be accepted as an abnormal finding that could create an impaction which would alter gastrointestinal motility and obstruct the movement of ingesta. For most of these factors, a reference frequency for the exposure expected in horses without colic is not known, such as how many horses without colic have equivalent amounts of hair in their intestine without developing an impaction. Most colic studies are of this second type, case reports and case series. In the third type, the controls used for comparison to provide a reference are other colic cases, other hospital cases or healthy population controls. Few population based studies are available. Selection factors for cases and controls may introduce bias. These studies are frequently limited because information is not available for controls. Some studies have used other colic cases not of the type of interest as a control group for comparing risk, which requires the assumption that the types of colic are clearly defined and independent. A control group with a disease related to the disease being studied may introduce bias and make interpretation of risk difficult. Few experimental studies, the fourth type, have been performed except for parasite and toxic agents.

Therefore, experimental and observational studies without selection bias are needed. More knowledge is required before experimental studies can be designed. Larger numbers of horses and long study periods are required to examine the causal factors proposed. With this background, an observational study using a randomly selected farm population was conducted. A prospective study was chosen to allow determination of colic incidence, morbidity and mortality of a horse population on farms and collection of accurate exposure information on a wide variety of hypothesized risk factors. Logistic regression with random effects was chosen to account for the herd effects due to the experimental unit, horses being clustered on farms. Alternative methods of analysis did not allow herd effects to be considered as a random effect.

This report includes results from a prospective study of horses from a random sample of mid to large size farms from two counties in Virginia and Maryland, USA. In the literature review, the causes and risk factors previously reported are discussed. The study results are separated into four chapters because many risk factors were investigated and a large amount information generated. Each chapter covers a different aspect of the analysis, but all chapters are interrelated and come from the same population, study design and dataset. The materials and methods section for Chapter 3 presents a complete description of the full study. The materials and methods for the other chapters concentrate on the portion of the study that applies to the results reported in the respective chapter. Chapter 3 results and discussion concentrate on the technical problems concerning the analysis not addressed in the other chapters.

Chapter 4 reports the incidence and mortality rates for colic. The study population is described along with a description of the cases. Farm, gender, breed, age and use specific incidence densities are reported.

The cohort analysis of risk factors is reported in Chapter 5. Specific factors hypothesized to increase colic were decreased roughage intake, transport, recent pregnancy, decreased water intake, parasitic infection, high concentrate consumption, and high level of medical treatment. The study objective was to determine if the above factors, other farm or horse factors, nutritional or management practices and events and weather were associated with an increased risk of colic in horses or on farms in the study.

A short induction time was hypothesized between exposure to a risk factor and the development of colic. A nested date analysis was performed for event and weather variables to examine the association between an event and colic within a short time period following the event. This analysis also dealt with questions in the cohort analysis about whether a horse's categorization for some risk factors was influenced by events happening after the colic. The date analysis is reported in Chapter 6.

The General Discussion, Chapter 7, summarizes the analyses as a whole, and makes suggestions for improvement of this study. The risk factors and risk associated events found in this study are discussed in terms of previous work and needed future work to continue the study of risk factors for colic. It is hoped that these results will generate ideas for further observational studies with planned interventions to reduce the incidence of colic.

Chapter 2

Literature Review

Description and Pathology of Colic

Acute diseases of the equine abdomen that cause pain are commonly referred to as colic[2]. Colic is not a defined disease. The term "equine colic" refers to a group of behavioral signs and clinical abnormalities exhibited by the horse in response to abdominal pain. The owner recognizes the horse's behavior as colic, a potentially life threatening condition. The veterinarian is called to determine the underlying pathology that initiated the horse's pain, its seriousness and to treat the problem. Colic was the top-ranked disease in a survey on the frequency of medical problems treated by equine practitioners[4].

Lesions associated with colic have been categorized by anatomic location in the gastrointestinal tract and by type of pathology, as obstruction, strangulation, non-strangulating infarction, enteritis, peritonitis, ulceration or ileus[3,5,6,7]. Many specific types of lesions are included within each category. Much of the literature regarding colic consists of descriptions of specific lesions and their differential diagnosis, treatment and prognosis. The type of lesions involved for a large subset of colic cases is unknown either because surgery or necropsy were not performed or signs were not definitive to make a specific diagnosis or identify the involved anatomic site. The diagnosis for these undefined colic cases is frequently referred to as ileus, spasmodic colic, verminous arteritis or simple colic[6]. Parry[6] reported 29% of 79 cases treated at the University of Melbourne and White[3] reported 25% of 4279 cases treated at 14 university hospitals in the United States fit into this category. Abdominal pain may also occur with other types of diseases that involve the reproductive organs, bladder, kidney or liver and not the gastrointestinal tract[3].

Anatomy, Physiology and Postulated Colic Mechanisms

The equine gastrointestinal tract has several unique anatomic features. The horse has a relatively small stomach, enlarged comma-shaped cecum and a long, wide, relatively unattached large intestine that forms two U-shaped loops[8]. The horse has evolved to occupy an ecological niche that involves continuous grazing of forage[9] with no grain. Sixty per cent of the digestive capacity is in the cecum and large intestine where microbial fermentation of cellulose plays a major role in digestion.

Gastrointestinal motility and digestion is dependent on the type of diet and timing of feeding[10,11,12]. The gastric and small intestinal phases of digestion are relatively short; liquid markers reach the cecum in two to three hours after ingestion. Mechanical breakdown of solid matter and protein digestion occur in the stomach. Enzymatic digestion of protein, soluble carbohydrate and fat and absorption of nutrients take place in the small intestine. A small amount of microbial digestion takes place in the stomach and small intestine. Microbial digestion of remaining soluble carbohydrate and protein and all insoluble carbohydrate to volatile fatty acids occurs in the large colon and cecum. Mean transit time for liquid markers through the cecum was five hours and over 50 hours for the remainder of the large colon[13].

Clarke has reviewed and compared the physiology of equine digestion of a high-energy, low-forage diet fed twice daily to that of a steady state diet of frequent small meals that simulates grazing[12]. Shortly after a single large feeding, horses experienced a transient state of hypovolemia due to secretion of saliva, bile, gastric and pancreatic juices. A second period of hypovolemia was noted at six hours post-feeding due to colonic secretions. Activation of the renin-angiotensin-aldosterone system in response to hypovolemia led to renal and intestinal fluid absorption to restore fluid balance. Plasma volume was constant for horses with simulated grazing. A large meal altered the normal pattern of the small intestinal migrating myoelectric complexes (MMC) to one that was postulated to increase the transit rate of digesta into the large bowel and decrease the time for small intestinal digestion. The MMC patterns appeared unaltered by continuous intake feeding. Large shifts in fluid volume of the large colon were measured after a concentrated meal. First, fluid was secreted into the lumen for six to eight hours followed by a four hour absorptive phase of fluid and volatile fatty acids from the lumen. The horses fed a steady-state diet had a constant net absorption. Abrupt introduction of concentrates into a horses diet caused fluctuations in the large colon microflora due to bursts of intense fermentation that increased bacterial numbers, decreased luminal pH, and increased numbers of lactic acid producing bacteria. Clarke proposed that in the horse fed high concentrate diet twice daily, a cycle of subclinical carbohydrate overload-like states occur which could affect the mucosal integrity and the muscle activity of the large intestine. He suggested that physiological systems are in a delicate balance and that a disruption by disease, parasites or changes in management such as altered feeding interval, water deprivation or unavailability of salt may lead to digestive disorders.

Fluid imbalances, motility alterations, fluxes in microbial fermentation, parasite migration and bowel wall inflammation are speculated to be mechanisms that induce the pathological lesions involved in colic, obstruction, strangulation obstruction, non-strangulating infarction, and enteritis. Pain is a result of activation of inflammatory pain receptors or luminal distention or traction on the mesentery causing activation of stretch pain receptors[1]. Obstruction may occur from mechanical blockage of movement of ingesta, fluid and gas, or functionally as adynamic ileus, which is a lack of motility due to interruption of propulsive muscle contractions or nervous control[14]. Strangulation obstruction involves blockage with vascular compromise, either arterial, venous or both. Vascular compromise without obstruction occurs in non-strangulating infarction. Inflammation, such as in enteritis and peritonitis, involves damage through inflammatory mediators and fluid balance. As each lesion progresses further alterations in motility, gaseous production, fluid accumulation, ingesta reflux, interruption of digestion, damage to the intestinal wall and release of inflammatory mediators or endotoxin may occur. Systemic signs due to fluid and electrolyte imbalance, and cardiovascular deterioration may follow[1]. In simple colic the pain initiating pathology is resolved without progression to damage that is irreversible.

Colic Incidence and Prevalence

The incidence of equine colic for a randomly selected population of horses on farms is unavailable. The incidence of colic has been reported in several studies with differing definitions of the population at risk. In these studies the incidence reported was influenced by selection factors for the population at risk. Rollins and Clement[15] reported 9% out of 10,541 horses in an Arizona private equine practice had colic over a 5 year period. Bell and Lowe[16] reported an incidence of 27 severe colics in 255,916 horses (4 colics per 100,000 entrant-days) for horses competing in American Horse Shows Association events. Foreman and White[17] reported 118 colic visits (6%) out of 1929 ambulatory calls at the University of Georgia. Barrett et al.[18] using a telephone questionnaire reported that out of 19,850 horses treated at 78 Welsh veterinary practices during 1988, 1331 were colic cases. An incidence estimate of 6.7 colic cases per 100 equine cases per year could be calculated from this information. Uhlinger[19] measured an incidence of 26 cases/100 horse-years at risk in a prospective study of 14 non-randomly selected herds.

Colic case series reports are available for several referral or private hospital populations[20,21,22,23]. Cases included are influenced by the practice type, economic and prognostic factors which determine what cases are treated at the facility. Proudman[24] conducted a prospective survey of colic cases in a British practice, but did not include an estimate of the practice population size.

No incidence estimates are available for specific types of colic lesions. While colic as defined broadly is considered a common event, the frequency of any one lesion type other than the undefined colic is relatively rare. Most case series reports involve the cumulative cases seen at a referral hospital over multiple years. The relative frequency for specific types of colic was determined in a study of 14 university hospitals[3]. Large colon obstructions were the most frequently reported specific type of colic, (19.5%), followed by small intestinal strangulation, (12.6%), large colon strangulation, (7.2%), enteritis (5.5%) and other categories, (each less than 5%). Reported case fatality percentages vary from 6 to 84% depending on the method of disease classification used by researchers[3,18,25].

Review of Causes of Colic from Literature

No experimental models are available which produce intestinal lesions associated with colic except in some specialized types discussed below. Techniques have been used experimentally to surgically create the pathology associated with intraluminal obstruction, extraluminal obstruction or ischemic vascular damage due to strangulation. Intraluminal obstruction was produced by introducing a balloon through a pelvic flexure fistula[26]. Extraluminal obstruction was produced by surgically implanting polyethylene tubing threaded with suture and then later ligating the jejunum to the body wall in conscious ponies[27]. Vascular ischemia is produced by ligation of intestinal vessels[28,29].

Many causes have been suggested for equine colic, still only a few risk factors are supported by strong evidence. Parasites as causal agents are the best documented and the most widely accepted. Colic due to foreign materials in the gastrointestinal tract, toxic materials, bacterial agents, anatomic defects and neoplasia have been reported, but represent a small fraction of colic cases[3].

Parasites-----Parasites such as *Strongylus vulgaris* have historically been reported as the cause of a large proportion of colic cases[30,31]. Bennett[32] made the claim in 1972 that gastrointestinal parasites, most importantly *Strongylus vulgaris,* were the most common cause of interference in gut motility. He proposed that most types of colic lesions involve alterations in motility, with parasites being the predisposing factor and improper management or poor physical condition of the horse serving as the inciting factors. Occasionally parasites may be the sole initiating factor. He suggested that anthelmintic treatment and management designed to prevent foals from contact with contaminated fecal material should reduce colic incidence. Experimental studies have reproduced the gastrointestinal arterial lesions seen in naturally occurring parasitic infections and experimentally infected animals have exhibited colic signs[33]. Duncan[34] described experimental infections of worm-free ponies with a single dose of third stage *Strongylus vulgaris* larvae. Thrombosis of the anterior mesenteric arteries and later fibrous thickening of the arterial wall were noted. Colic signs were observed in three of nine infected foals between 13 and 17 days post infection. Holmes[35] used repeated smaller dose inoculations of third stage *Strongylus vulgaris* larvae and reported pathologic gross and arteriographic lesions of the intestinal arteries. Drudge[36] described lesions in the anterior mesenteric artery due to migrating larvae that cause ischemia, inflammation and infarction of the intestinal wall supplied by the affected arteries. He claimed that application of rigid parasite control programs should make colic virtually absent and cited an estimate that *Strongylus vulgaris* has a causal relationship in up to 90% of cases of colic. White[37] examined arteries of naturally infected ponies with scanning electron microscopy and described larva in arteries with thickened walls and large thrombi. White[38] conducted macroscopic and histological examinations of arteries from 18 clinical colic cases with non-strangulating infarction, finding arterial lesions, but only two cases with actual thromboembolic blockage of peripheral vessels. Becht[39] reviewed suggested mechanisms by which parasites could induce colic. They include mechanical damage, allergic irritation, interference with nervous innervation, interference with local intestinal blood flow, and alteration of intestinal motility. Recent reviews consider the role of vasoactive products liberated by parasites[28,40,41].

With the development of anthelmintics effective against large strongyles, the role of other parasites in colic has received more attention. Studies have implicated small strongyles in colic[42,43,44,45]. Uhlinger[42] monitored colic in four Pennsylvania herds with a history of benzimidazole resistant cyathostome infection and suggested the high level of colic was related to this parasite. Colic rates were 24 to 46 cases per 100 horse-years. Improving parasite control with more effective anthelmintics appeared to reduce colic rates to 15 cases per 100 horse-years and lower. British investigators have reported clinical signs of diarrhea, rapid weight loss, ventral edema and sometimes colic at the time arrested cyathostome larvae resume development or as a sequelae to treatment for a cyathostome infection[45]. Love et al.[44] reported colic in four of fourteen diarrhea cases associated with larval cyathostomiasis. The colics were described as mild, intermittent or severe. Although the colic reduction reported by Uhlinger is convincing for the herds she reported, the proportion of colic cases due to small strongyle infection is unknown. Based on other disease reports about cyathostomes, the association of small strongyle infection with more than a minor proportion of colic cases is difficult to make. An epidemiologic study of risk factors for clinical cyathostomiasis by Reid et al.[46] did not mention colic.

Tapeworms have been found near the ileocecal valve in association with intussusception in several case reports. Barclay et al.[47] found tapeworm lesions in five of nine horses with intussusceptions. Beroza et al.[48] reported on three horses with cecal perforation and peritonitis in association with *Anoplocephala perfoliata* and also reported finding tapeworms involved with a cecal torsion[49]. Gaughan and

Hackett[50] found tapeworm infestations in eight of ten cases of cecocolic intussusception and Owen et al.[51] described two cases of cecal intussusception with tapeworm infection. Owen after reviewing the literature and finding as many cases of intussusception without tapeworms as with tapeworms, concluded an inconclusive connection between tapeworms and colic. Tapeworms are proposed to interfere with gastrointestinal motility.

Low sensitivity of tapeworm assays makes diagnosis in horses difficult. Proudman and Edwards[52] performed a case control study comparing 116 horses with colic to 115 non-colic cases at a Liverpool referral hospital using a centrifugation-floatation method to identify tapeworms in feces of affected horses. No association was found between infection and colic of all types, odds ratio=1.58 (0.76-3.3). If colic was categorized by section of the intestine, ileocecal colic had an increased odds ratio of having tapeworms compared with other types of colic. Bello[53] estimated tapeworm prevalence in healthy animals at 13% in 1979. Beroza et al.[49] found tapeworms in 53% of 100 randomly selected clinically normal horses in New England and Lyons et al.[54] found 54% of horses infected in Kentucky. If tapeworms are prevalent in the equine population and a real colic risk factor, the types of colic attributed to tapeworms should be more frequent. Intussusception is a relatively rare type of colic, White[3] reported the relative frequency of ileocecal intussusception as 0.7% and ceco-large colon intussusception as 0.3% in a for of 14 university hospital study. While tapeworms were frequently mentioned in colic discussions five to ten years ago, currently they seem to receive little attention.

Heavy ascarid infections have been recognized by many authors to cause impaction in foals following treatment with anthelmintics that paralyze and kill the parasites (piperazine and organophosphates)[31,39]. Other case reports describe an abdominal abscess containing parasites and an obstruction of the small and large intestine in a foal treated with trichlorfon[55] and a small intestinal impaction in a foal treated with pyrantel pamoate[56].

Colic is described in horses in which large numbers of *Gasterophilus spp.* larvae (bots) were found in the stomach at post-mortem[39]. Drudge and Lyons[57] associated some types of colic to *Gasterophilus*, but because high infection levels in normal horses are so common, the association is not accepted as causal. Colic due to *Gasterophilus* has not been produced experimentally.

In review, the role of large strongyles in colic has strong experimental basis, but for other types of parasites, tapeworms, cyathostomes and *Gasterophilus,* the relationship to colic is less convincing. The use of effective anthelmintics for prevention is nonetheless clearly indicated. Current parasite burdens in horses would be expected to be decreased since parasite control programs are widely recommended and effective anthelmintics are available. The proportion of colic seen in 1995 that involve parasites would be predicted to be lower than in the past. Because colic incidence estimates are unavailable from prior to anthelmintic use, it is difficult to quantify the decrease. However elimination of colic with the use of anthelmintics as some authors had earlier predicted has not occurred.

Other Reported Abnormalities and Defects Associated with Colic-----Foreign materials have been demonstrated to obstruct the intestinal tract by impactions and enteroliths. Without an estimate of the frequency of foreign material in unaffected horses, it is difficult to evaluate how much the ingestion of foreign materials increases the risk of colic. Some of these materials such as hair, wood, or stones, may be ingested frequently by all horses and travel through the gastrointestinal tract without problem. The quantity involved and the contribution of other risk factors probably determine whether obstruction occurs. Sand impaction is common in areas with sandy soil. Rollins and Clement[15] reported that 31% of colic observed in an Arizona private practice were diagnosed as sand colics. Specht and Colahan[58] reported on 48 cases of sand impaction in Florida, 26 with concurrent large-colon torsion or displacement. Ragle et al.[59] reported on 40 cases of large or small colon impaction from California, ten with concurrent colonic displacement or volvulus. No studies have been done comparing the incidence of colic between areas with sandy soil and areas without sandy soil, in order to estimate the relative contribution of sand colic to the total number of colics. Intestinal obstruction and impaction due to hair[60,61], a paper bag[62], cloth, rope or twine[63], wood[64], and rubber fencing[65,66] have also been reported.

Enteroliths are formed from layers of mineral deposited around a metal or stone nidus and may cause obstruction if they become large or numerous. Blue [67] reported finding small metal fragments, stones, hair, cloth, plastic baling twine, and rubber tire fragments involved at the center of enteroliths. Other factors involved in the formation of enteroliths have been reported. Lloyd[68] reported higher frequency of enteroliths in California and speculated on the role of mineral content of water and diet, especially the high magnesium content of alfalfa, on enterolith formation. White[3] reported higher frequency of enteroliths in California, Indiana and Florida.

Colic has been associated with the ingestion of certain toxic plant materials. Uhlinger[69] reported an outbreak of lameness in ten horses, two of which also exhibited colic signs, that consumed black walnut wood shavings used as bedding. Rook et al.[70] reported an outbreak of large bowel impaction in eight of 38 miniature horses ingesting cockspur hawthorn fruit. Acorn toxicity involving colic signs is described by Anderson et al.[71] in three of seven horses in a pasture where wind and flood conditions were thought to prevent normal grazing leading to consumption of an abundant acorn mast. Castor beans, ragwort and oleander[72] have also been reported to induce abdominal pain.

Colic has been associated with blister beetles and drugs such as amitraz and atropine. Schoeb and Panciera[73] report on 21 cases of abdominal pain, depression and shock following ingestion of hay containing dead blister beetles. Auer et al.[74] reported impaction colic, depression, ataxia and muscle incoordination in three of four horses sprayed with amitraz for ticks. Roberts[75] reproduced the signs experimentally in horses with differing doses and routes and metabolites of amitraz. Ducharme and Fubini[76] reported three cases of complicated colic where atropine administered to relax gastrointestinal spasms decreased intestinal motility which led to cecal distention. They experimentally induced colic with atropine in three of five normal ponies. Few colics can be attributed to toxicity, usually colics associated with toxins are recognized as outbreaks with high attack rates, multi-systemic signs and the presence of an agent with known toxicity in other species. The conditions resulting in toxicity involve either the presence of unusual amounts of the agent or lack of feed availability.

Colic has been observed in some cases of colitis due to infectious agents including Salmonella[77], *Ehrlichia risticii*[78] and Clostridia[79]. Diarrhea is usually the predominant clinical sign with these agents, but occasionally cases are reported where colic occurs without diarrhea.

Strangulations and obstructions of portions of the intestine have been associated with congenital or acquired anatomic defects. Congenital defects such as mesodiverticular bands[80], Merkel's diverticulum[81], and abnormal mesocolic attachment[82] have been described. Hultgren[83] reported a genetic mutation causing aganglionosis of the terminal ileum, cecum and colon in white progeny of overo spotted horses in which the foals are born with a nonfunctional gastrointestinal tract.

Colic has been associated with trauma, although often the injury is not documented. Trauma has been implicated in causing colics associated with mesenteric rents[80], internal hernias such as diaphragmatic[84], or inguinal hernia[85] and intramural intestinal hematomas[86]. Serious defects such mesenteric tears[87], segmental ischemic necrosis[88] and cecal perforation[89] in the mare have been related to trauma from foaling. Lesions such as entrapments and displacements have been described that involve abnormal migration of intestine through normal gaps in the omentum or mesentery that lead to intestinal obstruction or strangulation[90]. Variations in the anatomy and position of the omentum, mesentery and abdominal organs may play a role in increasing the probability that abnormal displacements, such as gastrosplenic entrapment or nephrosplenic entrapment, may occur[91].

Neoplasia may predispose a horse to colic if the lesion alters motility or leads to obstruction. Pedunculated lipomas in older horses which wrap around some part of the intestine causing an obstruction, are the most frequent type of neoplasm associated with colic signs. Mason[92] reported a strangulation of the rectum by a lipoma. Blikslager et al.[93] reported 17 cases, including 15 ileal or jejunal strangulations, one colonic strangulation and one jejunal obstruction. Edwards and Proudman[94] reported 75 cases of intestinal obstruction due to lipomas. Colic is an occasional clinical sign in horses with lymphosarcoma. Rebhun and Bertone[95] reported two of 20 horses with lymphosarcoma experienced colic.

Adhesions formed following abdominal surgery are associated with strangulating obstructions[96,97]. A history of previous colic or abdominal surgery is noted in some colic case reports[90]. Ducharme et al.[98] reported that fatal gastrointestinal disorders occurred in 17 of 86 horses discharged from the hospital following surgery for colic and that 12 of 60 horses that survived had occasional colic episodes.

Colic is also a presenting sign of gastric ulcers. Murray[99] reviewed cases of colic that were examined by gastroendoscopy and found gastric ulcers in 91 of 111 colic cases, 57 without other abdominal abnormalities and 34 concurrently with other lesions. Endoscopy was performed only for selected cases, which was a major factor in observation of the high proportion of ulcers.

Other case reports of colic with identified abnormalities involve torsion of spermatic cord[100], ganglionitis[101], cecal fold hypoplasia[102], ganglioneuroma[103], granulosa cell tumor[104], carcinoid[105], meso-umbilical band[106], smooth muscle intestinal tumors[107], leiomyoma[108,109], incarceration of small intestine through the lateral ligament of the bladder[110], and ruptured pheochromocytoma[111]. Documented causes and identified risk factors are lacking for many colic cases involving strangulation and colonic torsion.

Proposed Nutrition and Management Risk Factors-----Nutritional risk factors proposed in the literature are feeding a diet with an imbalance of roughage to concentrate[112,113], feeding certain foodstuffs such as coastal Bermuda grass[114,115,116], spoiled feed[31], young protein-rich grass[117,118], coarse or poor quality roughage[114,119,120], pelleted feeds[23], cubes[121] or cracked corn[122]; over-feeding[31], grain engorgement[90]; underfeeding[15,32] and feeding on the ground[123,124].

Other risk factors mentioned for colic are inadequate water supply[116,125], bedding[120], poor dentition[126], or previous colic[7,98,127]. All of these reports are anecdotal or based on observations of case populations without comparable control populations.

Events and changes in management, exercise or nutrition are frequently mentioned in the literature as causes of equine colic. Associations of colic with weather[128], dietary changes[90,129], irregular management[32], change in exercise, either strenuous exercise[32] or exercise deprivation[31], pregnancy or recent foaling[20,130] or stressful events[31] such as water deprivation[129] or recent injury or disease[31,32] were suggested in early papers and the same factors have been repeatedly cited over the last 25 years. The original references are based on opinion, or anecdotal report without observational or experimental documentation. Few studies until recently have further defined or conclusively demonstrated these risks.

Case-control studies have compared the proportion of colic cases with history of a recent event to the proportion of non-colic controls with similar history. Management factors were examined by Cohen[131] in a prospective case-control study of colics. The study involved horses treated by Texas veterinarians using the next non-colic emergency treated by the same veterinarian as the control. Participating veterinarians collected information on changes in housing, stabling, diet, or horse activity level, recent deworming, vaccination or transport, plus other descriptive variables relating to history, nutrition, management and horse factors. Event variables significant in logistic regression analysis were recent change in diet, history of previous colic and previous surgery. Change in stabling conditions and recent change in horse activity level were significant as individual variables but not in multivariable analysis.

In another case-control study, Reeves[132,133] used cases and controls from five veterinary hospitals in northeastern United States and Canada. Information was collected on housing, stable and farm environment, pasturing, diet, exercise, and history of breeding, travel, or health problems. No event related risk factor was reported as significant. Logistic regression analysis showed significantly increased odds ratios for the following factors: use for breeding, Arabian breed, care by a trainer or manager rather than the owner and diet with a high proportion of corn. Horses with access to two or three pastures had lower risk than horses with no access to pasture.

The association of weather and other recent events to the occurrence of colic in the horse have been examined retrospectively for case series in an attempt to confirm the significance of these potential risk factors. Severe weather, weather changes and seasonal weather factors have all been linked with colic[128,134]. Rollins and Clement[15] showed higher incidence of colic in an Arizona practice during hot months and suggested heat stress as a possible cause. Foreman and White[135] reported no correlation between colic incidence and temperature, change in temperature, and change in barometric pressure in a study of colic cases in the University of Georgia ambulatory practice. Moore and Dreesen[136] found no consistent association with weather patterns in a study of thoroughbred mares in Kentucky. Proudman[24] found no correlation between colic incidence and mean monthly temperature, change in monthly temperature, monthly rainfall, and monthly rainfall weighted for temperature in a practice-based prospective study in England. Seasonal trends are frequently mentioned[137] and authors speculated trends reflect differences in the forage nutrient content and availability. Meagher[126] noted small colon impaction occurs in the fall and early winter. Specht and Colahan[58] noted that sand colics were more frequent from July through December. Wilson[138] reported that ulcers are more common during hot weather months and incarceration of the large colon by the suspensory ligament of the spleen is most frequent in the winter[91]. Todhunter et al.[139] could not demonstrate a seasonal difference for gastric rupture.

Reproductive events have been associated with colic due to acquired inguinal hernia for the stallion[85], colon torsion/volvulus in the post-partum mare[130,140] and cecal perforation[141] related to foaling. Torsion or volvulus is suspected to be related to the return to lush grass pasture for the mare with a foal at her side[117,142].

Other stresses[119], events, and changes are postulated to induce an effect on gastrointestinal function and motility. Bell and Lowe[16] estimated the probability of health problems and injuries at horse shows and found horses had the greatest risk of soft tissue injury, followed by severe colic and then other types of injury and laminitis. The most deaths were attributed to colic. No disease probability estimates are available for horses not at a show for comparison. In a case series report of all colics seen at a referral hospital, Morris et al.[23] found no relationship between feed change within 30 days or previous activity for different types of colic. Dabareiner and White[143] reported 54% of horses with large colon impaction had changes in their routine in the two weeks prior to the colic episode, the two most frequent changes being exercise restriction and phenylbutazone administration because of an injury. Reeves et al.[144] reported diet change, foaling, deworming, weather change, exercise change, recent treatment, shipping or illness for colic cases but used the information to compare cases that survived to those that died. A high number of animals transported during the year was suggested to be related to a higher colic rate in herds in a retrospective practice-based study of field colics by Uhlinger[145].

Most case series reports either for all types or specific types of colic include some analysis of whether different age, gender and breed groups occur more frequently in the case group than in the control group[7,14,22,94,115,146,147,148,149,150]. These comparisons are often conflicting and require careful interpretation because of varying case definition and potential bias due to population selections. Certain types of colic appear to have age and gender associations, such as the occurrence of meconium and ascarid impactions in foals. Several breed associations are reported but are often contradicted by other reports.

These proposed causal factors can only explain a fraction of colics that occur. Multiple factors may be necessary to precipitate an abdominal crisis since some of the abnormalities described above exist in the horse for a long time before the colic occurs.

Review of Epidemiological Studies and Methods

The association of disease to an event can be studied by either cohort or case-control or cross-sectional designs. In prospective cohort studies or follow-up studies, the exposure information is collected at the beginning of the study and the participants are followed over time for disease occurrence. This allows incidence to be measured. To estimate incidence, a large defined population of initially healthy animals is required. Enough individuals must be included to assure an adequate number of disease episodes occur during the observation period. Comparison of incidence between exposure groups is the basis for determining which factors increase risk[151]. Alternatively case-control studies can be used to analyze risk factors. In case-control studies, disease cases are identified and then controls are ideally selected from the same population from which the cases came. Exposure information is collected retrospectively[151]. Risk is determined by comparison of exposure between the disease group and the non-diseased controls. The major advantage of the prospective study design is the elimination of recall bias due to time between data collection and the disease event and differential recall between the controls and cases because of knowledge of the disease.

A ratio comparison between the incidence of the exposure category and a reference category gives an univariate measure of association for the individual risk factor[151]. An incidence density ratio is the measure of association for a follow-up cohort study. When multiple risk factors are of interest and extraneous factors that may affect the risk measured must be controlled, a multivariable analysis is required. Logistic regression methods are used for analysis of multiple risk factors[151,152]. The logistic regression analysis is used to select significant explanatory variables for a dichotomous outcome variable, disease or no disease. By forward or backward or other selection procedures, covariate variables are eliminated and confounding variables controlled. Examples of veterinary problems where logistic regression analysis has been applied to identify risk factors include reproductive disorders in dairy cows[153], chronic mastitis in dairy cows[154], calf morbidity and mortality[155,156], intramammary infection in dairy herds[157], cryptosporidium infection in dairy calves[158], post-partum anestrus in beef cows[159], foot abscess in neonatal pigs[160], and equine colic[131,132].

Herd effects are considered an important problem to be considered in veterinary epidemiological studies. The use of multivariable statistical methods for diseases of animals living in herds has been critiqued[161]. Because animals from the same herd are not independent, they are more alike due to management, housing and genetic factors than animals from different herds. Bendixen[162] cites three problems that may occur in the analysis: 1) overdispersion, less variation in the dataset than the population from which the data were collected resulting in very small standard errors and confidence intervals for estimated parameters, 2) confounding by herd and 3) interaction by herd. Five methods were compared by Curtis[163] to deal with the herd effect in logistic regression analysis, 1) ignoring it, 2) using herd as a fixed effect, 3) matching on herd and using a conditional logistic regression, 4) using logistic binomial methods with herd parameterized as a random effect or 5) analyzing at the herd level only. Random effects models were considered the better solution for studies. Random effects models have been developed by Mauritsen[164] which use matching by a group to model extra-binomial variation. A second constant term %SCL in the analysis represents the variation due to the random effects. Variations of the model that handle different types of data include, betabinomial, logistic-normal, logistic-binomial and logistic-binomial for distinguishable responses models[154,165]. Curtis and McDermott[156,166,167] have reported on veterinary application of the methods. Random effects also are thought to control for unmeasured herd variables that could be confounding[162,165].

Chapter 3

Methods for Cohort and Event Risk Factor Analysis: Technical Aspects

Abstract

A one-year prospective study was conducted on horse farms to estimate population based incidence, morbidity, and mortality rates of equine colic and to identify risk factors for equine colic. Farms with greater than 20 horses and owners willing to participate were enrolled from randomly selected horse owners from two adjacent counties of Virginia and Maryland, USA. Farm and individual horse historical and current management information was recorded using a questionnaire for 31 farms and 1427 horses. Owners kept calendars to record the occurrence of specified events and any changes from original information. Colic was reported by the owner when a horse was observed exhibiting a behavior indicative of abdominal pain. Farms were visited within 48 hours of a colic episode and every three months to update information.

Results of the study are reported in the next three chapters, this report contains details on technical aspects of the analysis. Sixty-two percent of recruited farms fully participated. Farms dropping out were more likely to have horses used for hunting than participant farms. Parasite levels on the farm as measured by the proportion of fecal samples with parasite eggs and farm specific colic incidence density were not correlated. Farm level analysis was hindered by low power.

Horse level risk factors were analyzed using the first colic for each horse and for all colics by univariate tests and multivariable logistic regression with farm as a random effect. The two analyses results were very similar and first colic analysis was used. Two analyses were performed using first colic data, a cohort analysis and a nested date analysis of events and weather. Farm as a random effects was significant for variables in univariate analysis. In logistic regression, with multiple variables included, the farm random effect was non-significant. Potential confounders; age, gender, breed, use, and stalltime were confounding in stratified analysis, but only age was significant in multivariable logistic regression models. Concentrate variables, dry matter intake level, frequency of feeding and concentrate type were strong risk factors that were interchangeable within the models. Separation of the effects was not achieved for this dataset.

Introduction

Comparison of incidence between exposed and non-exposed groups is the basis for determining risk factors. Cohort studies have been conducted in human[168] and occasionally in animal species[19,169,170,171,172,173]. Alternatively case-control studies are commonly used to analyze risk factors. A comparable control population of exposed and non-exposed animals without the outcome of interest is critical for either study method. Prospective cohort studies by design have comparable case and control groups because cases and controls come from the same population. Cohort studies allow the exposure to be measured prior to the disease event, eliminating recall and selection biases. Disease events must be relatively frequent to allow a cohort study to be done efficiently in terms of time and money. Cohort studies require a large study population and a careful follow-up to assure precise and unbiased incidence and risk ratio measures.

Logistic regression methods are used for analysis of multiple risk factors[151,152]. Because of the way herd animals are managed, herd effects are an important consideration in veterinary epidemiological studies[161]. Random effects models[154,156,166,167] are used to correct variance estimates that are lower than the true variance because they are computed based on independent animals rather than animals clustered in herds. Random effects also are thought to control for unmeasured herd variables that could be confounding[162,165].

In order to determine risk factors, a cohort study was completed to measure incidence of colic and evaluate farm, horse, nutritional, management, and event factors on the risk of developing colic in a randomly selected population of horses from farms. The techniques used in the study design and analysis are discussed and evaluated in this report.

Materials and Methods

Case Definition-----Colic was broadly defined as any abdominal disease causing a horse to show one or more signs of acute pain, such as turning head to flank, pawing, rolling, lying on back, lying down excessively or repeatedly, circling to lie down, stretching, kicking, positioning to urinate frequently, backing into corners, curling the upper lip, bloat, lack of defecation or holding head in odd positions. For the purpose of this study, all cases of colic were included with or without a specific diagnosis and cases were not differentiated by pathologic or anatomic characteristics. Colic cases from non-gastrointestinal lesions were not distinguished from gastrointestinal colic. Initiating factors were not considered specific for a type of colic lesion, one initiating factor could result in multiple types of colic or one type of colic could have different initiating factors in different horses. Colic was considered an acute disease with an induction time of less than two days. Horses were returned to the population at risk after a colic resolved. When colic was diagnosed in a horse that previously had colic during the study, the new episode was included in the study if onset was at least 48 hours after the end of a previous colic episode.

Sampling-----Farms were selected randomly and horses were sampled by cluster sampling by farm, all horses on the selected farm were sampled. A sampling frame of 1367 horse-owners from two adjacent counties, Loudoun County, Virginia and Montgomery County, Maryland, was compiled from equine infectious anemia (EIA) test applications, veterinarian client lists and county extension mailing lists. The counties covered a total land area of approximately 900 square miles just west of Washington DC, and were comprised of a mix of suburban and small community residential areas and farms. A simple random sample of 555 owners was selected from the list frame using computer generated random numbers. Owners were contacted by telephone in order of random selection until 50 farms with 20 or more horses on the farm sometime during the year, were identified. The criteria for farm size was chosen to include farms making management decisions for groups of horses rather than the individual horse. Farms with 20 or more horses were selected to maximize the number of horses studied while maintaining a feasible number of farms to be monitored.

Planned size of the study population was 2000 horses clustered on 50 farms. Using an anticipated incidence rate of 10 cases per 100 horse-years, and proportion of the total horse-time of 0.1 for exposed subjects and 0.9 for unexposed subjects, the power for this study to detect a rate ratio of 1.5 would be 0.5, and to detect a rate ratio of 2.0 would be 0.97[174].

Seven farm questionnaires were available from farms that dropped out at the beginning of the study. A Fisher's exact test was used to test for differences between participating and non-participating farms for state, farm size, farm type, and horse use categories.

Data collection and categorization-----Owners or their managers willing to participate were visited by investigators to enroll the farm in the study. Initial information collected included a farm history questionnaire, horse-list, individual horse management profiles, farm map, and samples of all feeds. The horse-list contained horse identification, age, gender, breed, use, time lived on the farm, and if the horse had a history of colic in the five years prior to the study. Categories of information for farm questionnaire and horse profile are described in Tables 3-1 and 3-2. Descriptions of categories developed from open-ended questions on horse-list, questionnaire and profile are described below.

Farms were assigned to four categories (breeding, boarding, lessons or training) according to predominant horse use specified by owners. Farm size was determined by the total number of horses on horse list during the year and categorized as less than or greater than 50 horses.

Horses were assigned to groups based on horse-list description for gender (male, female, castrated male), breed (Thoroughbred, Warmblood, Arabian, Quarterhorse, pony, crossbred (owner identified two breeds or crossbred) and other (American Saddlebred, Tennessee Walking, Andalusian, Morgan, Miniature, Mustang, Draft, Cleveland Bay, Donkey and Appaloosa), age (0-2 years, 2-10 years, $>$10 years) and use (eventing, racing, training or breaking, showing/show jumping, dressage, hunting, pleasure, lessons, breeding, young (not yet in use), and no use). The no use category includes adult horses described as pets, babysitters, companions, lead ponies, farm horses, retirees, horses being rested for rehabilitation, turned-out horses, unbroken horses and two year olds not in training.

Definition of nutritional variables: Nutritional variables were defined based on each horse's diet from the original profile information recorded when the horse entered the study. Horses were classified into one of seven diet groups based on feedstuffs reported on the profile: 1) pasture only, 2) pasture and hay, 3) pasture and concentrate, 4) pasture, hay and concentrate, 5) hay and concentrate or 6) hay only. Since no colic episodes occurred in diet groups 1 (pasture only) and 6 (hay only), a forage only diet group was formed from groups receiving no concentrate (1, 2 and 6). Young horses (foals, weanlings and yearlings) were classified as a separate group because their diet was changing as they grew older. For other variables in this analysis, no adjustment was made for young horses.

Concentrates were classified by investigators from the brand name or description provided by the owner as 1) commercial pellet, 2) commercial or custom sweetfeed, 3) mixture, (either called a mix by the owner or being fed a combination of pellet and sweetfeed and/or other components) or 4) whole grain such as oats or barley. Horses were categorized into mutually exclusive groups by the concentrate type received. A second categorization of the horses receiving a mix feed placed horses into non-mutually exclusive groups based on whether they received pelleted feed, sweetfeed or whole grain as a component of their diet. The pellet category in this case included horses with pellet either as the only concentrate fed or part of a mixture.

A full unit of delivery of concentrate (can, quart, bucket, etc.) was weighed for each feed sample and nutrients were determined for the feed by the Forage Testing Laboratory, Virginia Tech. Using the feed analysis, dry matter intake of concentrates was calculated from the amount fed for each concentrate (number units fed per day x weight of one unit x dry weight percentage). If dietary analysis was unavailable, nutritional information for a feedstuff was estimated from an average of similar feedstuffs analyzed in the study (for example bran analysis was available from all but one farm; the average value was used for the missing farm) or values from National Research Council's Nutrient Requirements of Horses [175] were used. Crude protein and digestible energy intake of concentrate were computed from the dry matter intake. These values were summed for every concentrate reported in the diet for each horse to obtain a total daily concentrate dry matter, protein and digestible energy intake for each horse. Intake values were ranked and four levels determined for classification of horses; none, low, middle and high intake by approximate terciles for each nutrient parameter.

Sequence of feeding of concentrate, hay and water was reported by the owner and categories assigned on the basis of the first component fed. If no feeding order was given, the concentrate and hay were fed together, the horse was classified as all; if the order varied between feeding times, the horse was classified as variable; or if the horse received only one component at a feeding or consumed only pasture, it was classified as no order.

Hays were classified as alfalfa, timothy, orchard grass or mixed grass by investigators from the owner description. Pastures were classified as clover, orchard grass, mixed grass, grass and weeds, or dirt. Owner description of hay intake on the profiles was free-choice or in some measurement of pounds, flakes or bales. A reliable numerical estimate of hay intake was not possible without better defined measures. Hay intake was classified either free choice, measured or no hay.

Other nutritional classifications included whether horses received a daily vitamin-mineral or commercial supplement in addition to a plain or trace-mineralized salt block; if they received additional feedstuffs besides concentrate (such as bran, beet pulp, corncobs, corn oil, calf manna, linseed meal, or soybean meal); if they received a daily treat (such as apples, carrots, sugar or candy); or, if they received a medication in their daily diet. The total number of additives a horse received besides concentrate were counted. Profile and calendar entries were used to classify horses as being fed bran daily, infrequently (weekly or occasionally), or not at all.

Pastures were sampled on each farm once during the spring, summer and fall. Nutrients were determined for the pasture samples at the Forage Testing Laboratory, Virginia Tech. Farms were ordered by crude protein and digestible energy levels for pasture for each season. Farms were ranked as above or below the median protein or energy value of farms for each season, spring, summer and fall. Protein and digestible energy for hay samples were handled similarly. If multiple samplings of hay were available from a farm, a mean was used to assign the high or low ranking. Pasture and hay quality was handled as a farm variable.

Definition of History variables: History variables were based on the most recent date for events reported on the horse's profile. Since foals born in 1991 would have no opportunity to have a history of any problem and would distort the none category, they were excluded from the population used for these calculations.

Definition of Event variables: The owner/manager was given a calendar with instructions to record the occurrence of colic, change of horse use, horse movement off and back to the farm, and horse disease, treatment and fatalities, specified events or any changes in the profile information for any horse. Each farm was visited every three months to collect the calendars, update the horse-lists, collect baseline profile for new horses and sample new types of feed.

Calendar entries were classified by the investigators according to major events such as treatment, veterinarian visit, transport, parasite control, vaccination, farrier, breeding, foaling, disease (lameness, depression, diarrhea, respiratory infection, colic, fever, or injury), management alteration or unusual event; or changes from the original profile such as nutrition or exercise changes. The number of events or changes during the year in each category was tabulated for each horse and used to assign the horse into frequency categories, none, low and high. Nutrition events were subclassified as changes involving concentrate, hay, bran or additive. Events referring to a treat such as apples were excluded, because reporting appeared to vary greatly between farms. Management events were further classified as a 1) stable, pasture or paddock change, 2) routine horse care such as clipping, weighing, pulling mane, or bathing, 3) farm maintenance such as using fly spray, liming fields, or changing bedding, 4) breeding-related event such as starting lights, or 5) problem, non-routine, or unusual event such as a horse show, snowstorm, or horses running free due to a broken gate.

Definition of Health Events: Calendar health entries were further classified by type, body system, time, and diagnosis. Treatments and veterinary visits the day of a colic episode were omitted from event categories because they could have happened after the colic. Treatments and veterinary visits were categorized as 1) drug, 2) therapy (such as massage, hose, or wrap), 3) routine care (such as Coggins test, dentistry, prepurchase examination, or reproductive palpation), 4) diagnostic (examination, laboratory tests or radiographs for a specific problem) or 5) surgery (such as castration or suturing). Days of treatment were totalled for categories 1 and 2. Body system was assigned for each treatment, veterinary visit or health event. A descriptive diagnosis was assigned for each problem being treated based on calendar entries. Problems often had multiple entries if treated for several weeks and seen several times by a veterinarian. Because reasons for all events were not always included, if more than seven days had elapsed between treatments or visits, two events were considered different problems. Treatments with phenylbutazone or steroids without a stated reason were classified as non-specific inflammation. Other events without a specified reason were classified as unknown. Total number of health problems and number of different problems for the year were counted for each horse.

Horses were classified by the anthelmintic used for parasite control during the year: 1) ivermectin only, 2) other product only, 3) ivermectin and another product or 4.) none. The number of anthelmintic administration events were counted for each horse and classified.

Horses were classified on whether they received one or more vaccinations during the study. They were also classified on whether they were vaccinated at least once for tetanus, encephalomyelitis, rabies, rhinopneumonitis, influenza, monocytic ehrlichiosis (PHF), strangles, or other disease.

Definition of Horse-time: When a horse left the farm, the horse was removed from the study during the time it was off the farm and brought back into the study if it returned. Horses were classified on whether or not they entered the study after the initiation date for their farm, left the farm before the end of the study or had multiple starting dates indicating they had left and returned to their farm.

Because the horse population was dynamic, total horse days on the study were tabulated for each horse to allow for computation of incidence density based on the actual time the horse was under surveillance for colic during the study year.

Parasite sampling: Fecal samples were collected from 5 horses on each farm at the quarterly visit. The number of parasite eggs per gram of fecal sample were counted by the McMaster's method[176]. The proportion of positive fecal samples (>0 eggs per gram) was determined for each farm. This variable was evaluated as a farm variable.

Definition of Weather variables: Local meteorologic data collected at the Dulles International Airport located in Loudoun county, were retrieved from the National Climatic Center in Asheville, North Carolina. Barometric pressure, high and low temperatures, precipitation and humidity were recorded for each day of the study.

Colic reports: Colic was defined and the signs listed as part of the initial instructions. Instructions to the owner included reporting any horse behavior indicative of colic by telephone to the investigators. Farms reporting colic were visited within 48 hours to obtain information about the colic episode and to update changes in the horse information if necessary. Cases of colic were tabulated and reviewed by the investigators to confirm that each case met the case definition. Colic episodes were classified according to the diagnosis made by the attending veterinarian or called non-specified colic if the diagnosis was not known. Horses that died during the year were classified by cause and the colic proportional mortality rate was calculated. Complete data were collected for one year on each farm, with farms starting staggered from November, 1990 to January 1991 and completing between November 1991 and February 1992.

To maintain confidentiality, farms were numbered and only the investigators visiting the farms were aware of farm identity. Care was taken not to discuss information about other farms during visits and results were not returned until the study was completed to prevent owners from altering their management practices during the study.

Analysis-----Factors were analyzed in two steps; at the farm level and at the horse level. Farm information was entered into Epi Info (Center for Disease Control, Epidemiology Program Office, Atlanta GA), questionnaires and horse data were recorded on Lotus 123 (Lotus Development Corporation, Cambridge MA) spreadsheets. Spreadsheets were imported to dBase IV(Borland International, Scotts Valley, CA) for sorting, sums, counts and categorical grouping. Descriptive statistics were done using Epi-Info, Lotus 123, Quatro-Pro (Borland International, Scotts Valley, CA) or dBase IV software. Logistic regression was performed using

EGRET (Statistics and Epidemiology Research Corporation, SERC, Seattle, WA). Hosmer-Lemeshow tests were performed on Statistix software (Analytical Systems Inc., Tallahassee FL).

Farm-level analysis: Farm characteristics were screened as explanatory variables by univariate statistical tests. Farm specific incidence densities were ordered from low to high. The lower two-thirds were classified as low incidence farms, the upper third of the farms as high incidence farms. Divisions into these groupings followed two characteristics of the farm incidence distribution, 2/3 of farms were below the study crude incidence and 1/3 above and when number of farms was plotted no farms fell between 10 and 15 colics per 100 horse-years incidence density. Risk ratios and the level of significance between different categories of farm factors were computed by chi-square or Fisher's exact tests. For nominal variables the category with the highest frequency was used as the baseline for the risk ratio, for ordinal variables the lowest or none category was used as baseline. A large number of these tests failed to yield a result due to cells with zeroes. A second method, a Kruskal-Wallis ANOVA was used to test for differences between the incidence density values of farms in different exposure categories. Factors with a p value $<=0.25$ for a difference between categories were selected for inclusion in a farm level logistic regression.

Variables selected at the farm level univariate testing, were tested as explanatory variables for high colic incidence on the farm in a stepwise forward logistic regression. The farms were classified as above, a high incidence farm was in the top third of all farms ranked according to farm specific incidence densities (ID > 0.1, $n=11$) and a low incidence farm if they were in it ranked in the lower two thirds of farms, (ID $<= 0.1$, $n=20$). A p-value $<=0.05$ was used as the criteria for logistic regression.

Horse-level analysis: For horse variables, the incidence density ratio (IDR), defined as the incidence density of the exposed group divided by the incidence density of the unexposed group, was used to determine if a variable posed a significant risk for colic [151]. Incidence density (ID) for each exposure category of a variable was computed by dividing the number of colic cases experienced by horses in the category (numerator) divided by the total horse days accumulated by the horses belonging to the category (denominator). A baseline exposure category was selected for each variable, the category with no exposure if available. The ratio (IDR) of the exposure category ID relative to the baseline category ID was computed with its 95% confidence interval (CI). Each IDR was tested for difference from 1 by a z-test with the corresponding p-value determined. A variable with an IDR with $p<=0.1$ was selected for inclusion in a horse level logistic regression.

Variables selected at the horse level were tested as explanatory variables for presence of colic in a random effects stepwise forward logistic regression. Farm, age, breed, use, concentrate intake, and stall time were chosen as potential confounders for variables prior to analysis. Farm was used as the random effects variable. The variable with the lowest p-value was selected at each step as the variable that most improved the analysis until no additional variables could be added that significantly improved the analysis ($p<=0.05$). Interaction terms were tested by fitting the individual terms in pairs with a term for the interaction (variable 1 x variable 2). Interaction terms with $p<=0.05$ significance were introduced into the analysis with all terms to test for significance. Farm variables selected by univariate testing were checked for significance in the final horse random effects logistic regression model. Hosmer-Lemeshow (HL) tests were performed on the final set of variables to check the goodness of fit for the analysis. Since the software for this test has no random effects model capabilities, the HL test was used for the analysis without random effects. Odds ratios and confidence intervals for the total population were computed based on the best fitting analysis.

The contribution of farm as a random effect was tested by comparing the final analysis with the random effect term (%SCL) included to the analysis without the term. The significance of the difference was determined from the square root of the likelihood ratio statistic against a one-tailed normal distribution. The first step involved testing each variable individually with and without the random effect which gives indication of the strength of the random effect term for the variable.

Two models, one using the first reported colic for each horse (86) and one using all reported colic cases (104), were assessed by logistic regression. Population size for the first colic analysis was 1427. To use all colics, a horse that had multiple colic episodes was re-entered into the study as a new horse, making the population size 1445.

Nested Event Analysis: In the cohort analysis, events were analyzed by frequency, counted for the year of the study. For colic cases this time included time after the colic and changes may have been made after the colic occurred. A second analysis of the cohort was performed in a manner similar to a nested case-control study with the events analyzed relative to a specific date for each horse to improve the time relationship between the colic event and the event being evaluated. Since event information was already available for all horses, the whole cohort was used. Randomly selected dates were used for the controls. A matched nested case-control analysis precluded the use of the logistic binomial method for random effects. Matching on the date requires conditional logistic regression which does not allow a second matching for farm to handle the random effect. Another way to handle the farm effect would have been to match for both date and farm. This was not possible since farm and date were sometimes highly confounded, for example events such as anthelmintic treatment were often done to all the horses on a farm on one day.

Colic cases were assigned the date of their first colic episode. Horses without colic were assigned a random date within the time they were on the study. A number between 14 and the total number of days a horse was on the study was selected using a computer random number generator function (Quatro Pro). This number was added to the first start date to yield the random-date used for the control. Dates were adjusted for horses leaving and returning during the study to assure the horse was under observation for events for 14 days prior to the random-date. Horses on the study less than 14 days were assigned their last day.

To classify events, all events for each event type for each horse were compared to that horse's random-date or colic-date. If an event occurred less than 15 days before a colic-date or random-date, it was classified as exposure. The random-date or colic-date itself was excluded since events on that day may have happened in response to the colic. Some horses had multiple events occurring within the two weeks so each horse was classified as exposed if it had at least one exposure event of the type being evaluated. In addition to colic being evaluated within 14 days of foaling, foaling variables were used for colic within 60 to 150 days after foaling and 0 to 90 before foaling. A variable was developed for colic within 14 days of a horse starting the study or returning to the study after being off the farm. Significant events within 14 days, (vaccination, fever and transport) were also examined for the times 15 to 28 days and 29 to 42 days after the event to demonstrate the risk was specific for the event. Weather was analyzed similarly to horse events for time periods: the day of, 1 day before and 2 days before the colic-date or random-date. Barometric pressure was also analyzed for a decrease over 2 or 4 days or increase over 3 days before the colic-date or random-date.

Because events are acute exposures an odds ratio was calculated rather than an IDR. The odds ratios comparing the number of horses for recent event exposure to no event exposure for each event were computed. Fisher exact tests or chi square tests were used to test for significance level. Logistic regression with farm as a random effect was used to select significant ($p<=0.05$) event factors with control for other events and for previously identified risk factors for this cohort. Events were tested in a forward stepwise-logistic regression to select significant events. Only the recent vaccination variable, not the individual vaccine variable was used. Non-event related variables from the logistic regression analysis of the cohort (age, history of colic, level of concentrate dry matter in daily diet, and whether a whole grain was included in the diet) were added to the event factors forward-backward selection step. Variables from the previous analysis relating to event frequency (number of concentrate changes, number of hay changes and PHF vaccination during the study year) were excluded since they were replaced by new event variables. Finally, all variables originally significant as individual variables in univariate testing that were used to perform the cohort logistic regression analysis were retested with the event variables to see if any added significantly to the analysis. For the final logistic regression analysis, multiple history variables formed a singular matrix with the foals as a separate group, so foals were included with the no exposure group to allow computations to converge to a final maximum likelihood value. The significance of the random effects term was tested by comparing the analysis with or without the random effects term, the difference in the deviance is used to obtain a p value. Interactions were tested by first testing by logistic regression the variables in pairs with an interaction term (variable 1, variable 2, and variable1 X variable2). Interaction terms with a p-value$<=0.05$ were then tested in the analysis with all main effect terms previously selected. If the analysis was significantly improved by the addition, all variables or interactions with p-value$<=0.05$ were maintained. Goodness of fit of the analysis was confirmed by a Hosmer-Lemeshow test. To examine the strength of variables that had significant explanatory potential for the analysis, but were not selected because another related variable was stronger (ie had a lower p value), the significant variables were individually removed from the analysis and replaced by alternative variables to check how the analysis would be affected.

Additional analyses: A potential bias of concern was if farms reporting more events overall also reported more colic, than farms that reported fewer events. To assess the strength of this relationship, a Spearman's correlation coefficient was computed between the farm specific colic incidence density and the total number of events per horse year reported on the farm.

To try to separate the effects of the nutritional variables concerning concentrate, horses were stratified by concentrate dry matter level intake, concentrate feedings per day and concentrate type. Analysis was performed on the adult population in an attempt to reduce variation due to measures that would not be comparable between young horses and adult horses. For example a low intake value in young horses doesn't have the same meaning in relation to the horse's weight as that same level for the adult horse. New variables were defined to incorporate the information from multiple variables and eliminate categories with no data and tested in the logistic regression analysis replacing the individual concentrate variables.

Results

Results describing the colic episodes and farm and horse risk factors analysis are fully described in Chapters 4, 5 and 6. Additional technical details and analysis concerning the results are reported here.

Thirty-one farms (62%) of those contacted completed all initial questionnaires, kept calendars and reported colics. Nine owners declined participation during telephone contact. Of the forty-one farms with enrollment visits, ten failed to complete initial information or decided not to continue shortly after initiation. During the year three farms ceased operation for financial or personal reasons, these were included in the study up to the time the horses were dispersed. The total horse population including new horses added to farms during the study year was 1427 horses.

The incidence density for the year was 10.6 colic cases per 100 horse-years, based on 104 colics per 358,991 horse-days (983.5 accumulated horse-years). Based on the actual participation, 1000 horse-years, power was recalculated based on incidence rate of 10 cases per 100 horse-years, and proportion of the total horse-time of 0.1 for exposed subjects and 0.9 for unexposed subjects. The power to detect a rate ratio of 2.0 would be 0.75 instead of 0.97 originally projected[174].

Comparison analysis between participating and non-participating farms (Table 3-3) showed that the drop-out farms were significantly more likely to have horses used for hunting than farms that participated in the study ($p=0.03$).

The Spearman's correlation between number of all types of events reported by a farm and the farm specific incidence density was 0.50 (Figure 3-1). Farms ranged from 6.8 to 148.7 events per horse-year reported (Median = 39.5/horse-year). All 31 farms reported at least one nutrition, veterinary visit, vaccination, transport, farrier, and parasite control event during the year. One or more treatment events were reported by 30 farms, management events by 29 farms, breeding events by 12 farms, colic by 25 farms, exercise change by 21 farms, foaling by 16 farms, diarrhea by 6 farms, fever by 16 farms, injury by 25 farms, lameness by 25 farms, and respiratory disease by 17 farms.

Farm-level analysis-----The farm level univariate risk factor analysis was done by two methods, Fisher exact test and Kruskal-Wallis (KW) test (Table 3-4). Five variables would have been selected by the Fisher's exact test that were not selected by the KW test, and five variables were selected by the KW test that would not have been selected by the Fisher's exact test. Count data such as this are usually handled by computing risk ratios and using a chi-square statistic to test for differences. A Fisher's exact test was substituted to improve precision when expected cell values were less than five. Computing risk ratios required designating a baseline category for the comparisons and categorizing the farms as high or low incidence. Since farm numbers were low, this led to many categories with zero values and variables with no result. The use of the KW method gave results for all variables. P-values for the KW test tended to be lower than p-values for the Fisher's exact test which increased the number of variables that were considered in the farm level logistic regression.

Figure 3-2 shows the relationship between parasite levels on the farms, measured by the proportion of samples with parasite eggs, and the farm specific colic incidence density.

No variables were selected in the farm level logistic regression. A meaningful logistic regression analysis for farm variables could not be attained due to the low number of farms (n=31). Some variables had categories with zero farms in the high and low colic classifications. The logistic regression program would not model 6 of 15 selected variables when tested individually or any multivariable analyses. The variables were examined to reduce the number of categories but the analysis could not be improved.

Horse-level analysis-----The 104 colics were experienced by eighty-six horses. Seventy-two horses (84%) had 1 colic episode. Fourteen horses (16%) had more than 1 colic episode during the year with 11 of these having 2 colic episodes, 2 horses having 3 colic episodes and 1 horse having 4 colic episodes. The crude incidence density for all colics was 10.6 colic cases per 100 horse-years, based on 104 colics per 358,991 horse days (984 accumulated horse years). The incidence density for first colic was 9.1 colic cases per 100 horse-years, based on 86 colics per 346,151 horse days (948 accumulated horse-years).

The horse level univariate risk factors were selected for multivariable analysis based on all colic IDR, reported in Chapter 5. The horse level risk factor analysis for first colic is in Tables 3-5 to 3-9. The two analyses were very similar, the first colic analysis baseline ID values are slightly lower and confidence intervals wider due to lower number of colics and less horse-years. Several variables were selected by the all colic analysis that would have not been evaluated if the first colic analysis had been used to screen variables, (time the horses were on the farm, additive changes during the year, history of PHF vaccine, eye health problems, and more than one type of concentrate in diet). One additional variable, health problem within the last month, would have been included based on the first colic univariate analysis. P-values for these variables fell between 0.04 and 0.1 for all colic and above 0.1 for first colic. The difference between the two analyses reflected the added weight of horses with more than one colic for factors to which those 16 horses were exposed. None of these variables was important in multivariable analysis either for first colic or all colic.

Fifty-nine horse variables were selected for inclusion in multivariable analysis (Tables 4-2 to 4-6). The two logistic regression models for the models are Tables 3-10 and 3-11. The major difference between the two models was the nutritional variables selected, concentrate dry matter intake is slightly more important than concentrate in the first colic analysis. The variables are reversed in the all colic model. The Hosmer-Lemeshow tests indicated a good fit for both analyses, p=0.86 for all colic and p=0.69 for first colic. The first colic analysis was chosen as the best analysis for further work on events because it involves no independence violations between the subjects.

Final significant horse variables found by multivariable analysis for first colic are described in Table 3-11. The factors that significantly increased the risk of a horse for colic were 1) changes in amount and type of concentrate feeding during the year compared to no change, 2) age category 2-10 years compared to younger and older age groups, 3) history of previous colic compared to no previous colic, 4) change in the type of hay being fed more than once during the year, 5) feeding higher levels of concentrate compared to none, and 6) vaccination for Potomac Horse Fever during the year. Feeding a whole grain with or without other concentrate components had decreased the risk of colic compared to diets without grain.

Cribbing had marginal significance (p = 0.10), but was not selected in the multivariable model for increasing risk of colic.

Age was the only pre-identified confounder included in the final analysis, other than farm. Breed, gender, stall-time, and use were not selected as significant. Forcing these confounders into the final analysis made no change in the significant variables selected or the size of the odds ratios, so they were not included.

No interaction terms were significant in the cohort analysis, the closest interaction, between history of colic and number of concentrate changes having a p-value of 0.05 when tested with the two main effects and one interaction but a p-value of 0.08 when tested in the full analysis.

The random effect was highly significant for most variables when tested individually by logistic regression (Tables 3-12 to 3-16). The difference between the full analysis with and without the random effect was not significant (p=0.5) and the beta coefficient of the random effects term was 0.32E-16. In the full analysis other terms have controlled the farm confounding making the random effect term negligible.

Several concentrate variables showed indications of multicollinearity. Concentrate intake was the variable posing the highest risk (p=0.0006), but models with this variable replaced by concentrate feeding frequency (p=0.004) or concentrate type (p=0.016) were also valid. The model would accommodate any one of three variables. However if two concentrates variable were included, the model was statistically improved, but no longer differentiated between categories of either variable.

Stratified analysis for concentrate variables is in Table 3-17. The three way analysis yielded many estimates based on very small numbers for some categories. IDR were computed relative to the no concentrate group which had a low incidence density of 3 colic cases per 100 horse-years. Trends of increasing risk is evident as concentrate intake increased, as number of feedings increased and for concentrate types, pellet and sweetfeed over mixes and whole grains but confidence intervals are very wide and IDR couldn't be computed for many categories because of no colics or no horses. Analysis by two way pairings, Tables 3-18 to 3-20, indicated the same trends and didn't help to resolve which characteristics of concentrate feeding are more important. Logistic regression using redefined variables with collapsed categories for low concentrate intake, no concentrate intake and whole grain and combined information was also unsuccessful. Models with three-way combination variables would not converge to a fitted model. For two-way pairings, the variable combining concentrate type and frequency of feedings per day was the slightly more explanatory, p=0.0009, than concentrate level and type, p=0.006, or concentrate level and frequency of feedings, p=0.007. The variables, concentrate level and whole grain, from the original model were the best fitting variables, p=0.0003. The differences between these models are negligible. All three variables are strong risk factors for equine colic, interchangeable within the logistic regression analysis.

Nested event analysis-----The regression analysis with the events related to colic-dates or random-dates is listed in Table 3-21. Significant event variables were recent vaccination, recent transport, recent fever, and foaling within 60-150 days. Weather variables added to the other event variables were marginally significant, snow, p=0.06, and low humidity, p=0.06. Variables significant in the cohort analysis, concentrate events, hay events, and PHF vaccination, were replaced by newly defined event variables. When variables significant in the cohort analysis were included, concentrate dry matter intake, history of colic, and whole grain remained significant. Age, 2-10 years, p=0.13, was no longer was significant. Additional variables that could be introduced to the model were history of encephalomyelitis vaccine and vices. Significant interaction variables were grain and recent transport and grain and vices. Snow, p= 0.11, was not significant in the last analysis with all possible variables included. HL test indicated a good fit, p=0.78.

Discussion

Study size was less than planned. Analysis on the farm level was especially affected by low power in both the univariate and multivariable analysis. Many questions examined on the farm level had multiple responses. Factors with more than two categories had very sparse data. While the KW method is not the usual method for examining risk factors, it gave a better evaluation of farm factors because it allowed more farms in each category. The Fisher's exact test required categories to be divided again into high and low colic groups. The purpose of the univariate analysis was to identify factors where a difference between categories existed that could be explanatory for colic risk. The designation of a baseline in the middle of the ranges of risk may obscure differences if the ends are not different from the middle. In this situation the goal was to determine whether the top and bottom categories were different. The risk ratio would give a better indication of this type of difference, but the numbers were not available to get a meaningful measure. Basically there were too few farms to do anything with the farm level logistic regression.

Another problem was farm questions in which answers fit into multiple categories, (some horses this, some that) which were better analyzed on the horse level. On the horse level no farm factors were significant.

Study size impact on horse level analysis was evident in the wide confidence levels. Multiple risk factors were significant, there was no evidence of having too few variables significant because of power.

The technical issue involved in the horse level analysis was whether to use all colics or only the first colic experienced by each horse. The analysis using only the first colic for each horse is statistically preferable to the analysis using all colics because all cases are independent. However it means that some of the colics can't be used. In the all colics analysis, horses with more than one colic had more influence than horses with only one colic. Both analysis selected the same variables in the logistic regression except for the nutritional terms regarding concentrate. In the first colic analysis, the concentrate intake is stronger than concentrate type, in the all colic analysis, concentrate type is stronger than intake. The variable related to whether whole grains were in the diet was included in both analyses.

Horse level logistic regression yielded seven significant variables. Regression diagnostics indicated no problems. Confounding is an important bias to control in all epidemiologic studies. Factors that have effects mixed with the effects of interest can have a major distorting effect[177]. Logistic regression is used in multivariable analysis to measure the effect of one variable while controlling all others that are used in the analysis. Factors considered possible confounding variables in this study were farm, age, gender, breed, intake of concentrate, pasture/stall time, and use. The effect of farm was controlled by the random effects term. The effect of farm appeared to be minimal in the final analysis with all variables included, the random effects term was not significant. While age and concentrate intake were selected for the analysis, breed, use, and gender when forced into the analysis ignoring their statistical value as explanatory variables did not change the analysis.

Attempts to separate the effects of the three nutritional variables were unsuccessful. Based on the strength of all three variables, concentrate intake level, concentrate feeding frequency and type of concentrate, all are considered important risk factors for colic. To select one based on minor differences in performance in the model would be ignoring the risk demonstrated by the other two variables. An explanation of how the three variables interact however is beyond the power available from these data.

Analysis of variables by a combined cohort and nested analysis allowed the risk factors to be examined for both long term risk and short term risk, according to which attribute is of interest. Nested analysis of events relative to a date rather than by frequency during the study year as in the cohort analysis was more informative for assessing short term risk for events. Association of colic with transport, fever, foaling and weather were detected by this method that were not indicated in the cohort analysis. PHF vaccination and concentrate and hay event variables appear to have been influenced by events and changes that occurred after the colic episode. Alternately these factors may have risks that are not closely associated to the actual change but more to the cumulative effects of changes over time. The risk for recent vaccination was very strong, but risk was not specific for one vaccine type. Trying to select one type of vaccine over the others by logistic regression would be misleading since most were significant. Number of vaccines given, the variable used in the cohort analysis, was not very explanatory. Further study with efforts to separate these effects is necessary to explain this result.

In conclusion, previous colic, increased concentrate intake and/or concentrate type, recent vaccination, recent transport, recent systemic illness, foaling two to five months ago, recent snow, recent low humidity, and vices increase the risk of colic on farms with 20 or more horses in Loudoun county Virginia and Montgomery County Maryland.

TABLE 3-1 FACTORS IDENTIFIED ON THE FARM HISTORY QUESTIONNAIRE

HORSES ON FARM	Number; Years horses on farm; If number changes with season; If horses visit (during year); Use
LAND USE	Farm purchase date; Previous use; Other species; Crops
EMPLOYEES	Number; Full time or parttime; Employee number per task.
FEED	Source; Frequency of feeding; Order of feeding; Shipment frequency; Storage of hay; Where fed; If feed analyzed; Salt availability; Use of supplements.
WATER	Source; Delivery system; Frequency of checking availability.
HABITAT	Bedding type; Frequency of bedding changes; Frequency of stall cleaning.
PASTURE	Type; If fertilized, clipped, seeded, dragged; rotated, or manure removed; Soil type.
DISEASE/MEDICAL HISTORY (past 5 years)	Type of disease; Frequency of parasite control.
RECORDS	If breeding, feeding, training or health records kept.

TABLE 3-2 FACTORS IDENTIFIED ON THE INDIVIDUAL HORSE PROFILE

HAY	Type; Amount; Feeding frequency; If hay left after feeding; Order of feeding.
CONCENTRATE	Type, Amount; Feeding frequency;
SUPPLEMENTS	Vitamin-Mineral type and amount; Additive type and amount; Treat type.
PASTURE	Type; Time on pasture per day; Size.
WATER	Method; Intake estimate; If buckets emptied.
HOUSING	Stall time per day; Bedding; Paddock type; Paddock time per day; If shed available in paddock; Where housed.
BEHAVIOR	Habits; Place in pecking order; Temperament.
EXERCISE	Time worked per day.
BREEDING	Last breeding date; Last foaling date; Last weaning date.
MEDICAL	Type and date of: Injury or illness within last year, last vaccinations; last medication; last veterinary visit; last surgery; Last transport date; Last farrier visit.

TABLE 3-3 COMPARISON BETWEEN STUDY FARMS AND FARMS INITIATING BUT NOT CONTINUING IN THE STUDY

Variable * p< =0.05	Study Farms(31)	Drop-Out Farms(7)	p value Fisher's exact test
State	MD(8), VA(23)	MD(1), VA(6)	1.00
Farm Size	<25(14), 25-50(11), >50(6)	<25(3), 25-50(3), >50(1)	1.00
Farm type	Boarding(9) Breeding(12) Training(5) Lessons(5)	Boarding(3) Breeding(1) Boarding and Breeding (1) Training(1), Lessons and Training(1)	0.34
Farms with horses used for specific purpose	Boarding(12) Stallions(7) School(4) Pleasure(18) Western(1) Show(12) Dressage(9) Racing(12) Harness racing(1) Eventing(10) Endurance(1) Hunting(10)	Boarding(5) Stallions(3) School(2) Pleasure(4) Western(1) Show(4) Dressage(4) Racing(3) Harness racing(1) Eventing(4) Endurance(0) Hunting 6)	0.20 0.35 0.30 1.00 0.34 0.42 0.20 1.00 0.34 0.39 0.03*
How long farm owned	< =5 years(9) > 5 years(22)	< =5 years(4) > 5 years(3)	0.20
History of previous colic on farm	Yes(18), No(13)	Yes(5), No (2)	0.42

TABLE 3-4 COMPARISON OF FISHER'S EXACT TEST AND KRUSKAL-WALLIS (KW) TESTS FOR UNIVARIATE ANALYSIS OF FARM VARIABLES

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Farm				
State MD(8)	3	1.1(0.4-3.1)	1.0	0.51
VA(23)	8	B		
Time horses kept on farm*				
>=5 years(26)	8	2.0(0.8-4.9)	0.32	0.07
<5 years(5)	3	B		
Time farm owned by present owner*				
>=5 years(28)	8	3.5(2.0-6.3)	0.04	0.005
<5 years(3)	3	B		
Previous use other than horse farm				
Yes(23)	9	1.6(0.4-5.8)	0.68	0.80
No(8)	2	B		
Current use other than horse farm				
Cattle(12)	5	1.3(0.5-3.4)	0.71	0.45
None(19)	6	B		
Employees FT=fulltime, PT=parttime				
Low number employees				
>3 FT+PT(20)	6	0.7(0.37-1.7)	0.45	0.66
<=3FT+PT(11)	5	B		
High number employees				
>10 FT+PT(6)	2	0.9(0.3-3.2)	1.00	0.72
<10 FT+PT(25)	9	B		
Low number FT employees				
FT>2(18)	7	0.8(0.3-2.2)	0.72	0.74
FT<=2(13)	4	B		
More PT than FT employees				
PT>FT (8)	3	1.1(0.4-3.1)	1.00	0.27
PT<FT (23)	8	B		
No PT employees				
PT>0(19)	6	0.8(0.3-1.9)	0.71	0.55
PT=0(12)	5	B		

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Horses on farm				
Number resident horses				
>=25(17)	5	0.7(0.3-1.8)	0.48	0.44
<25(14)	6	B		
Visitor horses				
Yes(7)	4	2.0(0.8-4.8)	0.21	0.41
No(24)	7	B		
Boarder horses*				
Yes(12)	6	1.9(0.7-4.9)	0.26	0.19
No(19)	5	B		
Variation in number during year*				
=>10 difference(4)	0	A	0.27	0.04
<10 difference(27)	11			

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Feeding				
Concentrate(conc) source				
Home only(0),				
Commercial bag(24),	8	B		0.51
Commercial bulk(1),	0	A		
Combination (6)	3	1.5(0.6-4.0)	0.64	
Conc. feedings per day				
3x/day(6),	4	2.8(1.0-7.9)	0.13	
2x/day(17),	4	B		0.40
1x/day(1),	1	4.3(1.8-10)	0.28	
Variable(7)	2	1.2(0.3-5.2)	1.00	
Order of feeding				
Conc then hay(3)	1	1.1(0.2-6.5)	1.00	
Hay then conc(13)	4	B		0.61
Hay ad lib(4)	2	1.6(0.5-5.8)	0.58	
Together(3)	1	1.1(0.2-6.5)	1.00	
Variable(8)	3	1.2(0.4-4.1)	1.00	
Conc. shipment frequency				
<=1x/week(17)	7	B		0.45
>1x/week, <1x/month(11)	4	0.9(0.3-2.3)	1.00	
>=1x/month (3)	0	A		
Hay source				
Home grown(4)	0	A		
Locally grown(12)	4	B		0.83
Out of state(9)	4	1.3(0.5-3.9)	0.67	
Combination(6)	3	1.5(0.5-4.7)	0.63	
Hay feedings per day*				
3x/day(6)	5	3.3(1.3-8.4)	0.02	
2x/day(6)	2	1.3(0.3-5.5)	1.00	
Ad lib(16)	4	B		0.07
Variable(3)	0	A		
Hay shipment frequency				
<=1x/week(4)	1	0.7(0.1-4.1)	1.00	
1x/week, <=1/month(6)	2	0.9(0.2-3.3)	1.00	
>1x/month(16)	6	B		0.64
Variable(2)	2	2.7(1.4-5.0)	0.18	
None(3)	0	A		

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Hay storage				
Stable(19)	6	B		0.99
Haybarn(5)	2	1.3(0.4-4.5)	1.00	
Other or both(7)	3	1.4(0.5-4.0)	0.66	
Hay feeding method in stable				
Rack(5)	1	0.6(0.1-4.3)	1.00	
Floor(16)	5	B		0.86
Combination(10)	5	1.6(0.6-4.2)	0.42	
Hay feeding method in pasture				
Rack(4)	1	0.8(0.1-4.6)	1.00	
Ground(18)	6	B		0.72
None(3)	2	2.0(0.7-5.6)	0.53	
Combination(6)	2	1.0(0.3-3.7)	1.00	
Hay analysis done				
Yes(13)	3	0.5(0.2-1.6)	0.28	0.34
No(18)	8	B		
Salt usage				
Yes(31)	11	A		
No(0)	0	A		
Type of salt				
Plain white(4)	2	1.5(0.5-4.7)	0.60	
Trace-mineralized(24)	8	B		0.58
Both(3)	1	1.0(0.2-5.5)	1.00	
Salt feedings per day*				
Adlib(29)	9	B	0.12	0.11
Variable(2)	2	3.2(0.8-5.4)		
Salt feeding method				
Block(28)	9	B		0.18
Block and other(3)	2	2.1(0.8-5.4)	0.28	
Supplement usage				
Yes(27)	11	A		0.48
No(4)	0	A		
Supplement type*				
Mineral(1)	1	1.6(1.1-2.5)	1.00	
Vitamin(2)	0	A		
Mineral and vitamin(6)	1	0.3(0.04-1.7)	0.14	
Mineral, vitamin and electrolytes(5)	1	0.3(0.05-2.0)	0.29	
Other Combination(13)	8	B		0.16
None (4)	0	A		

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Supplement feedings per day*				
2x/day(5)	1	0.4(0.1-2.6)	0.36	
1x/day(17)	8	B		0.11
Ad lib(2)	0	A		
Variable(3)	2	1.4(0.6-3.7)	1.00	
None(4)	0	A		
Supplement feeding method				
Block(1)	0	A		
Mixed with conc(20)	8	B		0.37
Loose(0)	0	A		
Combination(5)	3	1.5(0.6-3.7)	0.62	
None(5)	0	A		
Supplements available in pasture				
Yes(8)	3	1.1(0.4-3.1	1.00	
No(23)	8	B		0.40

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Stable management				
Bedding type				
Straw(9)	2	0.7(0.2-3.5)	1.00	
Shavings(5)	3	2.0(0.6-6.6)	0.33	
Sawdust(7)	3	1.4(0.4-5.1)	0.64	
Combination(10)	3	B		0.59
Frequency bedding changed *				
1x/day(15)	6	B		0.17
>1x/day and <1x/week(5)	2	1.0(0.3-3.5)	1.00	
1x/week(5)	3	1.5(0.6-3.9)	0.62	
Other(6)	0	A		
Frequency stalls cleaned				
1x/day(21)	6	B		0.68
>1x/day(7)	4	2.0(0.8-5.1)	0.21	
Variable(3)	1	1.2(0.2-6.6)	1.00	
Water source for stable				
Well(30)	11	B		0.69
Other(1)	0	A		
Water delivery in stable*				
Automatic waterer(3)	2	2.1(0.8-5.4)	0.28	
Buckets(28)	9	B		0.11
Frequency water checked in stable				
>=3x/day(13)	6	B		0.87
2x/day(8)	2	0.5(0.1-2.1)	0.40	
1x/day(6)	1	0.4(0.1-2.4)	0.33	
Variable(4)	2	1.1(0.4-3.4)	1.00	
Frequency buckets cleaned in stable				
>=1x/day(18)	6	B		0.39
<1x/day(13)	5	1.2(0.5-3.0)	1.00	

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Pasture management				
Water source for pasture				
Well(25)	8	B		0.60
Ground(2)(pond, stream, or spring)	1	1.6(0.4-7.5)	1.00	
Well and ground(4)	2	1.6(0.6-4.9)	0.59	
Water delivery in paddocks/pastures				
Automatic waterer(8)	4	1.5(0.5-4.3)	0.65	
Buckets(3)	2	2.0(0.7-6.2)	0.53	
Tub(12)	4	B		0.70
Ground(2)	1	1.5(0.3-7.4)	1.00	
Combination(6)	0	A		
Frequency water checked in pasture				
>1x/day(4)	1	0.6(0.1-3.5)	1.00	
1x/day(19)	8	B		0.92
<1x/day(8)	2	0.6(0.2-2.2)	0.67	
Predominant forage type in pasture				
Grass(11)	2	0.4(0.1-1.5)	0.14	
Mix(19)	9	B		0.70
Weed(1)	1	2.1(1.3-3.4)	1.00	
Pastures fertilized*				
Yes(13)	7	2.4(0.9-6.6)	0.14	
No(18)	4	B		0.20
Pastures clipped				
Yes(30)	10	1.5(0.3-6.6)	1.00	
No(1)	1	B		
Pastures seeded				
Yes(15)	6	0.8(0.3-2.0)	0.89	
No(16)	5	B		0.49
Feces removed from pasture				
Yes(4)	1	0.7(0.1-4.0)	1.00	
No(27)	10	B		0.79
Pastures vacuumed				
Yes(0)	0	A		
No(31)	11	A		
Pastures rotated				
Yes(9)	4	1.4(0.5-3.6)	0.68	
No(22)	7	B		0.90
Pastures dragged or harrowed				
Yes(20)	6	0.7(0.3-1.7)	0.45	
No(11)	5	B		0.51

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Predominant soil type*				
Clay(18)	5	B		0.07
Black dirt(3)	0	A		
Rocky(2)	2	3.6(1.7-7.6)	0.11	
Unknown(3)	1	1.2(0.2-7.0)	1.00	
Combination(5)	3	2.2(0.8-6.1)	0.30	
Colic in past 5 years				
Yes(18)	7	1.3(0.5-3.4)	0.72	0.34
No(13)	4	B		
Strangles				
Yes(3)	1	0.9(0.2-5.0)	1.00	0.31
No(28)	10	B		
Potomac Horse Fever*				
Yes(6)	3	1.5(0.6-4.0)	0.64	0.05
No(25)	8	B		
Salmonella				
Yes(4)	3	2.5(1.1-5.7)	0.12	0.51
No(27)	8	B		
Gastric Ulcers				
Yes(10)	2	0.5(0.1-1.8)	0.26	0.83
No(21)	9	B		
Foal pneumonia				
Yes(6)	2	0.9(0.3-3.2)	1.00	0.92
No(25)	9	B		
Rhinopneumonitis				
Yes(1)	0	A	1.00	0.69
No(30)	11	A		
Botulism				
Yes(0)	0	A		
No(31)	11	A		
Other disease*				
Yes(11)	6	2.2(0.9-5.5)	0.13	0.22*
No(20)	5	B		

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Records				
Records kept on farm				
Yes(30)	11	A		0.78
No (1)	0	A		
Feeding records				
Yes(12)	4	0.9(0.3-2.4)	1.00	0.33
No(19)	7	B		
Health records				
Yes(29)	11	A		0.63
No(2)	0	A		
Breeding records				
Yes(18)	6	0.9(0.3-2.2)	1.00	0.37
No(13)	5	B		
Training records				
Yes(14)	5	1.0(0.4-2.6)	1.00	0.73
No(17)	6	B		
Frequency of deworming				
< 2 months(2)	0	A		
2 months(19)	9	B		0.54
3 or 4 months(4)	0	A		
Variable(5)	2	0.8(0.3-2.7)	1.00	
Proportion of fecal samples positive for parasite eggs (15 samples per farm, 1 farm not sampled)				
>0.2(14)	4	0.8(0.3-2.0)	0.70	0.40
<0.2(16)	7	B		
Pasture crude protein rank				
Spring				
High(14)	4	0.6(0.2-1.7)	0.44	0.71
Low(13)	6	B		
Summer				
High(10)	3	1.0(0.3-3.4)	1.00	0.29
Low(13)	4	B		
Fall*				
High(12)	2	0.4(0.1-1.5)	0.19	0.11
Low(11)	5	B		

TABLE 3-4 Farm Variable Categories (n) A=Not computed, cell with zero B=Used as baseline category * Selected for logistic regression	#High colic Farms (11)	Risk Ratio (RR) (95% CI)	P-value	
			Fisher's Exact	K-W
Pasture digestible energy rank				
Spring				
High(11)	5	0.7(0.3-1.8)	0.69	0.37
Low(16)	5	B		
Summer				
High(12)	3	0.7(0.2-2.4)	0.67	0.50
Low(11)	4	B		
Fall				
High(15)	3	0.4(0.1-1.4)	0.18	0.31
Low(8)	4	B		
Hay crude protein rank				
High(12)	3	0.6(0.2-1.7)	0.44	0.80
Low(18)	8	B		
Hay digestible energy rank				
High(9)	2	0.5(0.1-2.0)	0.43	0.64
Low(21)	9	B		

TABLE 3-5 HORSE VARIABLES: UNIVARIATE TESTS FOR FIRST COLICS ONLY
Incidence Density (cases per horse-year)

TABLE 3-5 HORSE VARIABLES * selected for LR		#colic	horse-years	ID	p-value z-test	IDR(95% test-based CI)
Gender	Female	36	424	0.08	0.46	0.8(0.5-1.3)
	Stallion	8	107	0.07	0.47	0.7(0.4-1.6)
	Gelding	42	418	0.10		
*Age	>10 years	15	237	0.06	0.47	1.3(0.6-3.0)
	2-10 years	61	500	0.12	0.003	2.6(1.4-4.9)
	<2 years	10	211	0.05		
*Breed	Arab	1	30	0.03	0.77	0.7(0.1-6.2)
	Quarterhorse	2	47	0.04	0.94	0.9(0.2-4.8)
	Pony	4	52	0.08	0.57	1.4(0.4-5.1)
	Other	3	48	0.06	0.66	1.4(0.3-5.7)
	Warmblood	9	69	0.13	0.05	2.9(1.0-8.2)
	Thoroughbred	62	594	0.10	0.07	2.3(0.9-5.6)
	Crossbred	5	110	0.05		
*Previous colic in the last 5 years	Yes	19	85	0.22	0.00002	2.9(1.8-4.7)
	No	67	863	0.08		
Time on farm	<=3 years	18	258	0.07	0.19	0.7(0.4-1.2)
	>3 years	68	690	0.10		
*Vices	any type	21	110	0.19	0.0002	2.5(1.5-4.0)
	No	65	839	0.08		
*Cribber	Yes	9	45	0.20	0.01	2.4(1.2-4.6)
	No	77	904	0.09		
*Temperament	Excitable	10	112	0.09	0.71	0.9(0.5-1.7)
	Aggressive	0	14	0		
	Normal or unspecified	22	293	0.07	0.22	0.7(0.4-1.2)
	Quiet	54	529	0.10		
*Pecking order position	Bottom	19	118	0.16	0.02	1.9(1.1-3.4)
	Top	13	163	0.08	0.90	1.0(0.5-1.8)
	Alone	2	9	0.23	0.14	2.8(0.7-11)
	Unknown	22	298	0.07	0.67	0.9(0.5-1.5)
	Middle	30	361	0.08		

TABLE 3-6 MANAGEMENT RELATED TO HOUSING AND PASTURE: UNIVARIATE TESTS FOR FIRST COLICS ONLY, Incidence Density (cases per horse-year)

TABLE 3-6 HOUSING VARIABLES *selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
Paddock used	Yes	13	114	0.11	0.38	1.3(0.7-2.3)
	No	73	834	0.09		
*Time in stall per day	23-24 hours	7	64	0.11	0.08	2.2(0.9-5.2)
	17-22 hours	22	184	0.12	0.006	2.4(1.3-4.5)
	9-16 hours	39	342	0.11	0.000	2.3(2.1-2.5)
	1-8 hours	2	40	0.05	0.99	1.0(0.2-4.3)
	None	16	319	0.05		
*Bedding used in stall	Shavings	20	185	0.11	0.02	2.2(1.1-4.1)
	Straw	15	180	0.08	0.15	1.7(0.8-3.3)
	Sawdust	30	207	0.14	0.0003	2.9(1.6-5.2)
	Combination	5	48	0.11	0.14	2.1(0.8-5.6)
	Unknown bedding	0	9	0	0.50	
	Not stalled	16	319	0.05		
Pasture type	Grass	22	253	0.09	0.39	1.6(0.6-4.6)
	Clover	27	258	0.10	0.22	1.9(0.7-5.3)
	Orchardgrass	26	257	0.10	0.24	1.8(0.7-5.2)
	Dirt	2	78	0.03	0.37	0.5(0.1-2.5)
	Weeds	3	28	0.11	0.37	1.9(0.4-8.5)
	No pasture	5	75	0.07		
*Pasture size	< 1	19	140	0.14	0.09	2.5(0.9-7.0)
	acre	35	338	0.10	0.22	1.9(0.7-5.2)
	1-10 acres	24	331	0.07	0.60	1.3(0.5-3.8)
	> 10 acres	4	67	0.06	0.90	1.1(0.3-4.4)
	Size unknown	4	73	0.05		
	No pasture					
*Number management events reported during year	1-3	30	311	0.10	0.008	2.2(1.2-3.8)
	4-10	26	171	0.15	0.00002	3.4(1.9-6.0)
	>10	12	62	0.19	0.00002	4.4(2.2-8.5)
	None	18	404	0.04		
*Number housing/pasturing changes reported during year	1-3	27	289	0.09	0.15	1.5(0.9-2.4)
	4-10	16	96	0.17	0.001	2.6(1.5-4.6)
	>10	9	47	0.19	0.002	3.0(1.5-6.0)
	None	38	542	0.07		

TABLE 3-7 MANAGEMENT RELATED TO USE: UNIVARIATE TESTS FOR FIRST COLICS ONLY, Incidence Density (cases per horse-year)

TABLE 3-7 USE VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Use	Lessons	1	63	0.02	0.64	0.2(0.03-1.7)
	Foal, Weanling, Yearling	5	154	0.03	0.21	0.5(0.1-1.6)
	Hunt	5	74	0.07	0.98	1.0(0.3-3.4)
	Pleasure	10	111	0.09	0.63	1.3(0.4-3.8)
	Breeding	15	164	0.09	0.58	1.3(0.5-3.6)
	Dressage	10	74	0.14	0.21	2.1(0.7-5.9)
	Show	11	80	0.14	0.19	2.0(0.7-5.6)
	Race	10	74	0.13	0.21	2.0(0.7-5.6)
	Training	5	31	0.16	0.17	2.3(0.7-7.7)
	Event	9	49	0.18	0.07	2.6(0.9-7.6)
	No use	5	73	0.07		
Breeding events recorded	Yes	4	53	0.08	0.71	0.8(0.3-2.3)
	No	82	895	0.09		
Weaning reported	Yes	9	143	0.06	0.23	0.7(0.3-1.3)
	No	77	804	0.10		
History of foaling (adult mares)	Yes	8	66	0.12	0.58	1.2(0.6-2.7)
	No	27	277	0.10		
Foaling in study year(adult mares)	Yes	10	83	0.12	0.61	1.2(0.6-2.5)
	No	23	231	0.10		
Time at work	>1 hour per week	26	263	0.10	0.40	1.2(0.8-2.0)
	>1 hour per day	19	173	0.11	0.25	1.4(0.8-2.4)
	None	41	512	0.08		
*Exercise changes reported	Yes	30	196	0.15	0.001	2.1(1.3-3.2)
	No	56	752	0.07		
*Number transports during year	1-6	46	418	0.11	0.03	1.6(1.0-2.5)
	>6	7	58	0.12	0.16	1.8(0.8-4.0)
	None	33	488	0.07		
Horse left and returned during the year (multiple start dates)	Yes	8	86	0.09	0.95	1.0(0.5-2.1)
	No	78	861	0.09		
Horse entered study after start	Yes	14	211	0.07	0.18	0.7(0.4-1.2)
	No	72	737	0.10		
History of Farrier in last 6 months	Yes	23	302	0.08	0.31	0.8(0.5-1.3)
	No	63	646	0.10		

TABLE 3-7 USE VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
Number farrier visits during year	1-3	20	269	0.07	0.44	0.8(0.4-1.5)
	4-6	26	252	0.10	0.85	1.1(0.6-2.0)
	>6	25	273	0.10	0.86	0.9(0.5-1.8)
	None	15	155	0.10		

TABLE 3-8 MANAGEMENT RELATED TO NUTRITION: UNIVARIATE TESTS FOR FIRST COLICS ONLY, Incidence Density (cases per horse-year)

TABLE 3-8 NUTRITION VARIABLES *selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Diet	Concentrate and pasture	3	16	0.19	0.02	5.5(1.3-23.0)
	Conc, pasture and hay	70	612	0.11	0.03	3.3(1.1-9.7)
	Conc and hay	5	74	0.07	0.36	1.9(0.5-7.9)
	Growing	5	161	0.03	0.87	0.9(0.2-3.7)
	Forage only	3	86	0.03		
*Conc dry matter	< 2.5 kg/day	13	253	0.05	0.24	2.1(0.6-7.1)
	2.5-5.0 kg/day	31	291	0.11	0.008	4.3(1.5-12.8)
	> 5.0 kg/day	39	283	0.14	0.003	4.2(1.6-10.9)
	0 kg/day	4	124	0.03		
*Conc crude protein	0.35 kg/day	21	322	0.07	0.08	2.5(0.9-6.9)
	0.35-0.75 kg/day	26	243	0.11	0.006	3.9(1.5-10.2)
	>0.75 kg/day	36	268	0.13	0.001	5.5(1.9-15.6)
	0 kg/day	3	121	0.02		
*Conc digestible energy	<10 Mcal/day	24	339	0.07	0.07	2.9(0.9-9.1)
	10-20 Mcal/day	25	241	0.10	0.01	4.2(1.4-12.7)
	>20 Mcal/day	34	245	0.14	0.001	5.7(2.0-16.1)
	0 Mcal/day	3	123	0.02		
*Conc type	Only Pellet	18	163	0.11	0.01	4.2(1.4-13.0)
	Only Sweetfeed	42	343	0.12	0.004	4.7(1.6-13.6)
	Combination or prepared mix	21	295	0.07	0.09	2.7(0.9-8.7)
	Only Grain	3	32	0.09	0.09	3.6(0.8-15.9)
	None	3	121	0.03		
*Conc feedings frequency	1/day	1	59	0.03	0.70	0.6(0.07-6.1)
	2/day	52	606	0.09	0.03	3.3(1.1-9.8)
	> 2/day	30	169	0.18	0.0003	6.8(2.4-18.8)
	0/day	3	114	0.03		
*More than type of conc	Yes	20	277	0.07	0.23	0.7(0.4-1.2)
	No	66	672	0.10		
Type conc part of diet	Pellet	29	286	0.10	0.47	1.2(0.8-1.8)
	No	57	662	0.09		
	Sweetfeed	57	602	0.09	0.59	1.1(0.7-1.8)
	No	29	346	0.08		
	Prepared Mixture	11	165	0.07	0.28	0.7(0.4-1.3)
	No	75	783	0.10		
	*Grain	12	206	0.06	0.08	0.6(0.3-1.1)
	No	74	743	0.10		

TABLE 3-8 NUTRITION VARIABLES *selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Sequence of feeding	Water first	5	52	0.10	0.48	1.5(0.5-4.1)
	Conc first	8	104	0.08	0.74	1.2(0.5-2.8)
	Hay first	38	401	0.09	0.26	1.4(0.5-2.8)
	None or only 1 component	6	130	0.05	0.46	0.7(0.3-1.8)
	Variable	16	65	0.25	0.0001	3.7(1.9-7.4)
	Hay and concentrate together	13	197	0.07		
*Hay feeding method	Measured	58	466	0.12	0.002	2.0(1.3-3.2)
	No hay	3	75	0.04	0.47	0.6(0.2-2.1)
	Free choice	25	407	0.06		
*Hay type	Timothy	56	591	0.09	0.14	2.3(0.8-7.2)
	Alfalfa	12	166	0.07	0.37	1.8(0.5-6.2)
	Orchardgrass	11	75	0.15	0.03	3.6(1.1-12.0)
	Grass Mix	4	42	0.09	0.26	2.3(0.5-9.9)
	No Hay	3	74	0.04		
*Hay feeding frequency	1/day	27	209	0.13	0.04	3.2(1.0-9.8)
	2/day	8	117	0.07	0.44	1.7(0.5-6.3)
	>2/day	27	220	0.12	0.06	3.0(1.0-9.4)
	Always available	21	329	0.07	0.46	1.6(0.5-5.2)
	Not fed:	3	73	0.04		
	Pasture only	0	53	0		
	Conc and pasture	3	21	0.14		
*Supplements(Vitamin-Mineral or other Commercial additive)	Yes	40	318	0.13	0.01	1.7(1.1-2.6)
	No	46	630	0.07		
Additives (non-commercial feedstuffs fed by owner in addition to conc)	Yes	12	97	0.12	0.26	1.4(0.8-2.6)
	No	74	851	0.09		
*Number of dietary supplements and additives in addition to conc and hay	1	22	243	0.09	0.38	1.3(0.7-2.1)
	2	19	141	0.13	0.02	1.9(1.1-3.2)
	>2	7	34	0.21	0.007	2.9(1.3-6.3)
	0	38	530	0.07		
Treats fed regularly	Yes	38	361	0.11	0.24	1.3(0.8-2.0)
	No	48	588	0.08		
*Bran usage	Daily	4	18	0.22	0.05	2.7(1.0-7.0)
	Weekly or infrequently	9	48	0.19	0.02	2.3(1.2-4.5)
	None	73	882	0.08		

TABLE 3-8 NUTRITION VARIABLES *selected for LR			#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Number nutritional changes during the year (not treats or bran)		1	12	133	0.09	0.20	1.5(0.8-3.0)
		2	12	121	0.10	0.12	1.7(0.9-3.3)
		>2	31	163	0.19	0.0000	3.2(2.0-5.2)
		0	31	531	0.06		
Changes reported	*Bran:	Yes	27	139	0.19	0.00001	3.0(2.0-4.3)
		No	59	809	0.07		
	*Hay:	1	13	153	0.09	0.55	1.0(0.6-1.9)
		>1	25	133	0.19	0.00004	2.8(1.8-4.2)
		No	48	698	0.07		
	*Conc:	1	21	116	0.18	0.00008	2.9(1.8-4.5)
		>1	16	108	0.15	0.005	2.9(1.8-4.6)
		No	49	725	0.07		
	*Additive:	Yes	15	119	0.13	0.18	1.6(1.0-2.6)
		No	71	829	0.09		

TABLE 3-9 MANAGEMENT RELATED TO HEALTH: UNIVARIATE TESTS FOR FIRST COLICS ONLY, Incidence Density (cases per horse-year)

TABLE 3-9 HEALTH VARIABLES * selected for LR		#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
(1991 foals excluded from history variables)						
History of health problem (1990 or later)						
	*Illness	16	74	0.22	0.0004	2.6(1.5-4.3)
	No	68	805	0.08		
	*Injury	18	97	0.19	0.002	2.2(1.3-3.6)
	No	66	781	0.08		
	*Treatment or antibiotic given	25	107	0.23	0.008	2.8(1.8-4.3)
	No	65	772	0.08		
*History of deworming in 1990	Yes	77	859	0.09	0.0001	0.2(0.1-0.5)
	No	7	19	0.36		
History in last 5 years	Surgery	6	37	0.16	0.18	1.7(0.8-4.0)
	No	78	841	0.09		
	*Colic	18	62	0.29	0.0000	3.6(2.2-5.8)
	No	66	816	0.08		
History of Vaccination in 1990						
	1 or more of any type	72	731	0.10	0.50	1.2(0.7-2.2)
	No	12	148	0.08		
	Tetanus	66	673	0.10	0.67	1.1(0.7-1.9)
	No	18	206	0.09		
	*Encephalomyelitis(combination)	60	500	0.12	0.007	1.9(1.2-3.0)
	No	24	378	0.06		
	*Rhinopneumonitis	64	588	0.11	0.07	1.6(1.0-2.6)
	No	20	290	0.07		
	Influenza	68	675	0.10	0.37	1.3(0.7-2.2)
	No	16	203	0.08		
	*Rabies	57	445	0.13	0.002	2.1(1.3-3.2)
	No	27	433	0.06		
	Strangles	18	139	0.13	0.16	1.5(0.9-2.4)
	No	66	739	0.09		
	*Monocytic ehrlichiosis(PHF)	31	267	0.12	0.19	1.3(0.9-2.1)
	No	53	611	0.08		

TABLE 3-9 HEALTH VARIABLES * selected for LR	#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
History of health problem in the month before started study: Any problem (recent veterinary visit, illness, phenylbutazone, antibiotic, treatment, surgery or injury	29	241	0.12	0.08	1.5(1.0-2.3)
No	57	707	0.08		
*Use of phenylbutazone	9	52	0.17	0.04	2.0(1.0-4.0)
No	77	896	0.09		
*Other treatment or antibiotic	10	59	0.17	0.04	2.0(1.0-3.8)
No	76	890	0.10		
Drug received daily on profile Yes	3	23	0.13	0.50	1.5(0.5-4.7)
No	83	926	0.11		
*Number health events during year 1-5	29	248	0.12	0.02	1.7(1.1-2.8)
>5	17	110	0.16	0.003	2.3(1.3-4.0)
0	40	590	0.07		
*Number veterinarian visits during year 1-5	51	485	0.11	0.06	1.6(1.0-2.6)
>5	12	114	0.11	0.18	1.6(0.8-3.2)
0	23	350	0.07		
Health events by type					
*Number drug treatments: 1-5	27	242	0.11	0.05	1.6(1.0-2.6)
>5	17	103	0.17	0.001	2.4(1.4-4.1)
0	42	604	0.07		
*Number therapy treatments: >0	17	112	0.16	0.02	1.8(1.1-3.1)
0	69	837	0.08		
Number routine health events: >0	50	486	0.11	0.05	1.5(1.0-2.3)
0	36	498	0.07		
*Number diagnostic health events: 1-5	31	287	0.11	0.15	1.4(0.9-2.2)
>5	6	30	0.20	0.03	2.5(1.1-5.7)
0	49	631	0.08		
Number surgical health events: >0	65	61	0.08	0.82	0.9(0.4-2.2)
0	98	888	0.09		

TABLE 3-9 HEALTH VARIABLES * selected for LR	#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
Health events by body system					
Reproductive	17	159	0.11	0.45	1.2(0.7-2.1)
No	69	790	0.09		
Gastrointestinal (other than colic)	3	20	0.15	0.40	1.6(0.5-5.1)
No	83	928	0.09		
Skin	12	93	0.13	0.19	1.5(0.8-2.7)
No	74	856	0.09		
Respiratory	6	66	0.09	0.99	1.0(0.4-2.3)
No	80	882	0.09		
*Musculoskeletal, nervous, hoof	29	197	0.15	0.003	1.9(1.2-3.0)
No	57	751	0.08		
Dental	23	222	0.10	0.47	1.2(0.7-1.9)
No	63	726	0.09		
*Non-specified, treated with anti-inflammatory drugs	16	91	0.18	0.005	2.2(1.3-3.7)
No	70	857	0.08		
Routine health care	39	374	0.10	0.26	1.3(0.8-1.9)
No	47	575	0.08		
Eye	2	20	0.10	0.91	1.1(0.3-4.4)
No	84	928	0.09		
Other	6	42	0.14	0.26	1.6(0.7-3.7)
No	80	906	0.09		
*Unknown (not classifiable in above categories)	30	237	0.13	0.03	1.6(1.0-2.5)
No	56	711	0.08		
Specific events reported by owner					
*Injury	15	94	0.16	0.02	1.9(1.1-3.3)
No	71	854	0.08		
Fever	5	33	0.15	0.22	1.7(0.7-4.2)
No	81	916	0.09		
Respiratory disease	4	51	0.08	0.76	0.9(0.3-2.3)
No	82	897	0.09		
Lameness	9	74	0.12	0.36	1.4(0.7-2.7)
No	77	874	0.09		
*Number of health problems reported 1-2	10	171	0.06	0.82	0.9(0.4-2.0)
3-5	29	284	0.10	0.11	1.6(0.9-2.9)
>5	29	206	0.14	0.007	2.2(1.2-3.9)
0	18	282	0.06		
*Number of different health problems reported 1-2	13	210	0.06	0.93	1.0(0.5-2.0)
3-5	47	400	0.12	0.03	1.8(1.1-3.1)
>5	8	51	0.16	0.03	2.4(1.1-5.5)
0	18	282	0.06		

TABLE 3-9 HEALTH VARIABLES * selected for LR	#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
Number of anthelmintic treatments reported 1-3	44	542	0.08	0.52	0.8(0.3-1.7)
4-6	31	301	0.10	0.96	1.0(0.4-2.2)
>6	4	40	0.10	0.94	1.0(0.3-3.3)
0	7	67	0.11		
*Anthelmintic used					
Ivermectin and other	45	348	0.13	0.009	1.9(1.2-3.0)
Other only	3	63	0.05	0.54	0.7(0.2-2.3)
Unknown	4	81	0.05	0.53	0.7(0.3-2.0)
None	7	67	0.11	0.14	1.5(0.7-3.5)
Ivermectin only	27	391	0.07		
Vaccination reported					
*Any type, (1 or more)	74	756	0.11	0.14	1.6(0.9-2.9)
No	12	193	0.07		
Tetanus	45	461	0.10	0.49	1.2(0.8-1.8)
No	41	487	0.08		
Encephalomyelitis	44	371	0.12	0.02	1.6(1.1-2.5)
No	42	577	0.07		
Influenza	57	608	0.09	0.68	1.1(0.7-1.7)
No	29	340	0.09		
*Monocytic ehrlichiosis (PHF)	57	446	0.13	0.0003	2.2(1.4-3.4)
No	29	503	0.06		
Rabies	29	265	0.11	0.23	1.3(0.8-2.0)
No	57	683	0.08		
Rhinopneumonitis	57	586	0.10	0.39	1.2(0.8-1.9)
No	29	363	0.08		
Strangles	13	115	0.11	0.39	1.3(0.7-2.3)
No	41	834	0.09		
Botulism or Rotavirus	3	52	0.06	0.41	0.6(0.2-1.9)
No	83	896	0.09		

TABLE 3-10 VARIABLES SELECTED BY LOGISTIC REGRESSION USING ALL COLIC EPISODES FOR EACH HORSE

Term	Beta-coefficient	Std Error	p-value	Odds Ratio	95%CI
%GM(intercept term)	-5.44	0.73	<0.001	0.43E-02	0.10E-02-0.18E-01
Conc=None				1.00	
Conc=Pellet	1.90	0.62	0.002	6.69	2.0-22
Conc=Sweetfeed	1.65	0.56	0.003	5.19	1.7-15.5
Conc=Mix	0.65	0.58	0.26	1.92	0.6-6.0
Conc=Grain	1.34	0.85	0.12	3.80	0.7-20
Conc events =0/study				1.00	
Conc events =1/study	1.31	0.29	<0.001	3.71	2.1-6.5
Conc events>1/study	1.20	0.30	<0.001	3.33	1.9-6.0
No History of colic				1.00	
History of colic in last 5 years	1.465	0.29	<0.001	4.28	2.4-7.6
No History of colic -1991 Foal	-0.11	0.86	0.90	0.90	0.2-4.8
Hay events=0/study				1.00	
Hay events=1/study	-0.37E-01	0.38	0.92	0.96	0.5-2.0
Hay events>1/study	0.99	0.27	<0.001	2.68	1.6-4.6
Age < 2 years				1.00	
Age 2-10 years	1.47	0.43	<0.001	4.33	1.9-10.1
Age >10 years	0.77	0.48	0.11	2.17	0.8-5.6
No PHF vaccine				1.00	
PHF vaccine during study	0.98	0.25	<0.001	2.67	1.6-4.6
%SCL (random effects term)	0.1215E-16	0.22			

TABLE 3-11 VARIABLES SELECTED BY LOGISTIC REGRESSION USING FIRST COLIC FOR EACH HORSE.

Variable	Beta-coefficient	Std Error	p-value	Odds Ratio	95%CI
%GM(intercept term)	-5.68	0.77	<0.00	0.3E-02	0.8E-03-0.2E-01
Conc=None				1.0	
Conc Intake=<2.5 kg/day	0.87	0.67	0.20	2.4	0.6-8.8
Conc Intake=2.5-5 kg/day	1.56	0.64	0.01	4.8	1.4-16.6
Conc Intake=>5 kg/day	1.85	0.64	0.004	6.3	1.8-22
No Whole Grain Fed				1.0	
Whole Grain Fed	-0.94	0.37	0.01	0.4	0.2-0.8
Conc events =0/study				1.0	
Conc events =1/study	1.07	0.32	<0.001	3.6	1.6-5.4
Conc events>1/study	0.77	0.32	0.02	2.2	1.2-4.1
No History of colic				1.0	
History of colic in last 5 years	1.29	0.32	<0.001	3.6	1.9-6.8
No History of colic -1991 Foal	0.32	0.85	0.70	1.4	0.3-7.3
Hay events=0/study				1.0	
Hay events=1/study	-0.68E-01	0.36	0.85	0.9	0.5-1.9
Hay events>1/study	0.75	0.30	0.01	2.1	1.2-3.8
Age < 2 years				1.0	
Age 2-10 years	1.03	0.43	0.02	2.8	1.2-6.5
Age >10 years	0.47	0.49	0.34	1.6	0.6-4.2
No PHF vaccine				1.0	
PHF vaccine during study	0.71	0.25	0.005	2.0	1.2-3.6
%SCL	0.32	0.17			

TABLE 3-12 HORSE VARIABLES, COMPARISON BETWEEN LOGISTIC REGRESSION WITH AND WITHOUT FARM AS A RANDOM EFFECT

TABLE 3-12 HORSE VARIABLES USED IN LOGISTIC REGRESSION		p-value logistic regression	deviance difference with and without random effects	p-value random effect
Gender	Female	0.68	9.865	<0.001
	Stallion	0.27		
	Gelding			
Age	>10 years	0.17	10.0	<0.001
	2-10 years	0.003		
	<2 years			
Breed	Arab	0.75	9.70	<0.001
	Quarterhorse	0.94		
	Pony	0.43		
	Other	0.62		
	Warmblood	0.11		
	Thoroughbred	0.05		
	Crossbred			
Previous colic in the last 5 years	Yes	<0.001	7.55	0.003
	No			
Time on farm	< =3 years	0.98	10.08	<0.001
	>3 years			
Vices	any type	0.004	5.49	0.01
	No			
Cribber	Yes	0.02	10.30	<0.001
	No			
Temperament	Excitable	0.22	10.96	<0.001
	Aggressive			
	Normal or unspecified			
	Quiet	0.75		
Pecking order position	Bottom	0.12	8.37	0.002
	Top	0.78		
	Alone	0.81		
	Unknown	0.47		
	Middle			

TABLE 3-13 MANAGEMENT RELATED TO HOUSING AND PASTURE, COMPARISON BETWEEN LOGISTIC REGRESSION WITH AND WITHOUT FARM AS A RANDOM EFFECT

TABLE 3-13 HOUSING VARIABLES USED IN LOGISTIC REGRESSION		p-value logistic regression	deviance difference with and without random effects	p-value random effect
Time in stall per day	23-24hours	0.92	5.18	0.01
	17-22hours	0.03		
	9-16hours	0.05		
	1-8hours	0.91		
	None			
Bedding used in stall	Shavings	0.14	3.65	0.03
	Straw	0.42		
	Sawdust	0.007		
	Combination	0.168		
	Unknown bedding			
	Not stalled			
Pasture size	< 1 acre	0.21	8.31	0.002
	1-10 acres	0.19		
	> 10 acres	0.37		
	Size unknown	0.83		
	No pasture			
Number management events reported during year	1-3	0.004	0.8	>0.05
	4-10	<0.001		
	>10	<0.001		
	None			
Number housing/pasturing changes reported during year	1-3	0.07	2.07	0.07
	4-10	0.007		
	>10	0.01		
	None			

TABLE 3-14 MANAGEMENT RELATED TO USE, COMPARISON BETWEEN LOGISTIC REGRESSION WITH AND WITHOUT FARM AS A RANDOM EFFECT

TABLE 3-14 USE VARIABLES USED IN LOGISTIC REGRESSION		p-value logistic regression	deviance difference with and without random effects	p-value random effects
Use	Lessons	0.30	4.62	0.016
	Foal, Weanling, Yearling	0.29		
	Hunt	0.74		
	Pleasure	0.42		
	Breeding	0.35		
	Dressage	0.42		
	Show	0.13		
	Race	0.35		
	Training	0.22		
	Event	0.29		
	No use			
Exercise changes reported	Yes	0.006	7.18	0.004
	No			
Number transports during year	1-6	0.63	10.0	<0.001
	>6	0.16		
	None			

TABLE 3-15 MANAGEMENT RELATED TO NUTRITION, COMPARISON BETWEEN LOGISTIC REGRESSION WITH AND WITHOUT FARM AS A RANDOM EFFECT

TABLE 3-15 NUTRITION VARIABLES USED IN LOGISTIC REGRESSION		p-value logistic regression	deviance difference with and without random effects	p-value random effects
Diet	Concentrate and pasture	0.04	8.84	0.001
	Conc, pasture and hay	0.05		
	Conc and hay	0.50		
	Growing	0.78		
	Forage only			
Conc dry matter	< 2.5 kg/day	0.20	6.83	0.004
	2.5-5.0 kg/day	0.01		
	> 5.0 kg/day	0.003		
	0 kg/day			
Conc type	Only Pellet	0.007	6.34	0.006
	Only Sweetfeed	0.01		
	Combination or prepared mix	0.09		
	Only Grain	0.77		
	None			
Conc feedings frequency	1/day	0.95	3.55	0.03
	2/day	0.03		
	> 2/day	0.002		
	0/day			
Type conc part of diet	Grain	0.08	7.77	0.003
	No			
Sequence of feeding	Water first	0.78	3.35	0.03
	Conc first	0.57		
	Hay first	0.40		
	None or only 1 component	0.51		
	Variable	0.006		
	Hay and concentrate together			
Hay feeding method	Measured	0.02	3.75	0.03
	No hay	0.08		
	Free choice			
Hay type	Timothy	0.19	6.77	0.005
	Alfalfa	0.45		
	Orchardgrass	0.22		
	Grass Mix	0.34		
	No Hay			

TABLE 3-15 NUTRITION VARIABLES USED IN LOGISTIC REGRESSION		p-value logistic regression	deviance difference with and without random effects	p-value random effects
Hay feeding frequency	1/day	0.11	6.81	0.005
	2/day	0.58		
	>2/day	0.06		
	Always available	0.57		
	Not fed: Pasture only			
	Conc and pasture			
Supplements(Vitamin-Mineral or other Commercial additive)	Yes	0.13	9.48	0.001
	No			
Additives (non-commercial feedstuffs fed by owner in addition to conc)	Yes	0.47	10.45	<0.001
	No			
Number of dietary supplements and additives in addition to conc and hay	1	0.77	10.17	<0.001
	2	0.05		
	0			
Bran usage	Daily	0.09	8.51	0.002
	Weekly or infrequently	0.06	0.06	
	None			
Number nutritional changes during the year(not treats or bran)	1	0.27	3.5	0.03
	2	0.5		
	>2	<0.001		
	0			
Changes reported	Bran: Yes	<0.001	7.57	0.003
	No			
	Hay: 1	0.43	3.14	0.04
	>1	<0.001		
	No			
	Conc: 1	<0.001	8.29	0.002
	>1	0.004		
	No			
	Additive: Yes	0.13	9.84	<0.001
	No			

TABLE 3-16 MANAGEMENT RELATED TO HEALTH, COMPARISON BETWEEN LOGISTIC REGRESSION WITH AND WITHOUT FARM AS A RANDOM EFFECT

TABLE 3-16 HEALTH VARIABLES USED IN LOGISTIC REGRESSION	p-value logistic regression	deviance difference with and without random effects	p-value random effects
(1991 foals excluded from history variables			
History of health problem (1990 or later)			
Illness	0.10	3.79	0.03
No			
Injury	0.07	5.43	0.01
No			
Treatment or antibiotic given	0.04	5.42	0.01
No			
History in last 5 years Colic	<0.001	5.40	0.01
No			
History of Vaccination in 1990			
Encephalomyelitis(combination)	<0.001	4.11	0.02
No			
Rhinopneumonitis	0.02	5.79	0.008
No			
Rabies	<0.001	4.53	0.02
No			
Monocytic ehrlichiosis(PHF)	0.31	7.12	0.004
No			
History of health problem in the month before study Use of phenylbutazone	0.33	8.77	0.002
No			
Other treatment or antibiotic	0.14	8.68	0.002
No			
Number of health events during year 1-5	0.05	4.96	0.01
>5	0.04		
0			
Number of veterinarian visits during year			
1-5	0.01	10.56	<0.001
>5	0.04		
0			

TABLE 3-16 HEALTH VARIABLES USED IN LOGISTIC REGRESSION	p-value logistic regression	deviance difference with and without random effects	p-value random effects
Health events by type			
Number drug treatments: 1-5	0.08	5.06	0.01
>5	0.03		
0			
Number therapy treatments: >0	0.10	8.09	0.002
0			
Number diagnostic health events: 1-5	0.25	7.89	0.002
>5	0.03		
0			
Health events by body system			
Musculoskeletal, nervous, hoof	0.02	5.79	0.008
No			
Non-specified, treated with anti-inflammatory drugs	0.03	6.72	0.005
No			
Unknown (not classifiable in above categories)	0.27	7.72	0.003
No			
Specific events reported by owner			0.003
Injury	0.06	7.62	
No			
Number of health problems reported 1-2	0.36	7.01	0.004
3-5	0.009		
>5	0.003		
0			
Number of different health problems reported 1-2	0.15	7.30	0.003
3-5	0.003		
>5	0.03		
0			
Number of anthelmintic treatments reported 1-3	0.48	8.46	0.002
4-6	0.09		
>6	0.32		
0			
Anthelmintic used			
Ivermectin and other	0.51	4.38	0.02
Other only	0.02		
Unknown	0.52		
None	0.92		
Ivermectin only			

TABLE 3-16 HEALTH VARIABLES USED IN LOGISTIC REGRESSION	p-value logistic regression	deviance difference with and without random effects	p-value random effects
Vaccination reported			
Any type, (1 or more)	0.02	8.30	0.002
No			
Encephalomyelitis	0.06	3.06	0.04
No			
Monocytic ehrlichiosis (PHF)	<0.001	5.00	0.01
No			

TABLE 3-17 INCIDENCE DENSITY STRATIFIED BY CONCENTRATE TYPE, CONCENTRATE DRY MATTER LEVEL AND CONCENTRATE FEEDING FREQUENCY, relative to no concentrate

Incidence Density Ratio relative to No Concentrate (0.03 colics per horse-year), IDR(95% Confidence Interval)				
Concentrate Dry Matter Intake Level Concentrate feedings/day	Concentrate Type			
	Pellet	Sweetfeed	Mix	Whole Grain
Low				
1/day	0*	2.6(0.3-28)	0*	0*
2/day	1.2(0.2-21)	2.2(0.4-12)	0.8(0.1-9.1)	0*
3/day	0*	7.5(1.7-34)	2.2(0.2-23)	0*
Mid				
1/day	0*	0*	0*	N
2/day	2.6(0.4-18)	4.9(1.3-19)	2.5(0.5-13)	0*
3/day	19(4.8-77)	7.8(1.7-35)	9.8(2.6-37)	N
High				
1/day	N	N	N	N
2/day	4.0 (0.9-18)	8.6(2.6-29)	0.9(0.1-9.6)	9.9(1.4-69)
3/day	6.5(1.6-26)	0*	8.9(2.3-35)	0*

*= No colics
N=No horses

TABLE 3-18 INCIDENCE DENSITY STRATIFIED BY CONCENTRATE TYPE AND CONCENTRATE DRY MATTER INTAKE LEVEL relative to no concentrate

Incidence Density Ratio relative to No Concentrate (0.03 colics per horse-year), IDR(95% Confidence Interval)			
Concentrate Dry Matter Intake	Concentrate Type		
Low, Mid, High Intake 1-3x/day	Whole Grain		
	3.5(0.6-22)		
Low, 1-3x/day	Pellet, Sweetfeed, Mix		
	2.2(0.5-9.6)		
	Pellet	Sweetfeed	Mix
Mid, 1-3x/day	4.3(0.9-20)	5.0(1.3-19)	3.6(0.9-15)
High, 1-3x/day	5.1(1.3-20)	8.6(2.5-29)	3.6(0.8-16)

TABLE 3-19 INCIDENCE DENSITY STRATIFIED BY CONCENTRATE TYPE AND CONCENTRATE FEEDING FREQUENCY relative to no concentrate

Incidence Density Ratio relative to No Concentrate (0.03 colics per horse-year), IDR(95% Confidence Interval)			
Concentrate Feeding Frequency	Concentrate Type		
1-3x/day, Low, Mid, High Intake	Whole Grain		
	2.5(0.4-14)		
1x/day, Low, Mid, High Intake	Pellet, Sweetfeed, Mix		
	0.5(0.1-4.8)		
	Pellet	Sweetfeed	Mix
2x/day Low, Mid, High Intake	2.3(0.6-8.4)	3.9(1.3-12)	1.1(0.3-4.5)
3x/day Low, Mid, High Intake	5.5(1.7-18)	4.8(1.4-17)	4.8(1.5-16)

TABLE 3-20 INCIDENCE DENSITY STRATIFIED BY CONCENTRATE DRY MATTER INTAKE LEVEL AND CONCENTRATE FEEDING FREQUENCY relative to no concentrate

Incidence Density Ratio relative to No Concentrate (0.03 colics per horse-year), IDR (95% Confidence Interval)		
Concentrate Intake Level	Concentrate Feeding Frequency	
Low Intake, All types	1-3x/day	
	2.1(0.5-9.0)	
Mid Intake, All types	1-2 x/day	3x/day
	3.5(0.9-14)	8.8(2.5-31)
High Intake, All types	5.5(1.5-20)	6.8(1.9-25)

TABLE 3-21 COMBINED SIGNIFICANT VARIABLES FROM COHORT AND NESTED DATE ANALYSIS

Variable	Beta-coefficient	Standard Error	p-value	Odds Ratio(95% Confidence Interval)
%Grand Mean	-5.10	0.63	<0.001	0.60E-02(.2E-02-0.2E-01)
Transport within 14 days	0.57	0.46	0.22	1.77(0.7-4.3)
Vaccination with 14 days	1.26	0.30	<.001	3.52(2.0-6.3)
Foaling within 60-150 days	1.62	0.52	0.002	5.00(1.8-13.8)
Fever within 14 days	2.70	1.19	0.02	14.8(1.5-151)
History of colic	1.43	0.34	<0.001	4.16(2.2-8.0)
Concentrate Dry matter intake				
>0, <2.5 kg/day	1.07	0.67	0.11	2.92(0.8-10.9)
2.5-5 kg/day	1.73	0.63	0.006	5.62(1.6-19.5)
>5 kg/day	1.97	0.63	0.002	7.14(2.0-24.8)
Whole Grain in diet	-2.05	0.57	<0.001	0.13(0.04-0.4)
History of encephalomyelitis vaccine prior in year before the study	0.57	0.26	0.03	1.76(1.1-2.9)
Vice	0.25	0.34	0.47	1.28(0.7-2.5)
Grain X Vice	2.05	0.79	0.009	7.7(1.7-36)
Grain X Recent Transport	2.23	1.05	0.03	9.27(1.2-73)
Snow	0.87	0.55	0.12	2.4(0.8-7.0)
Low Humidity	0.54	0.26	0.04	1.7(1.0-2.9)
% SCL	0.96E-15	0.29		

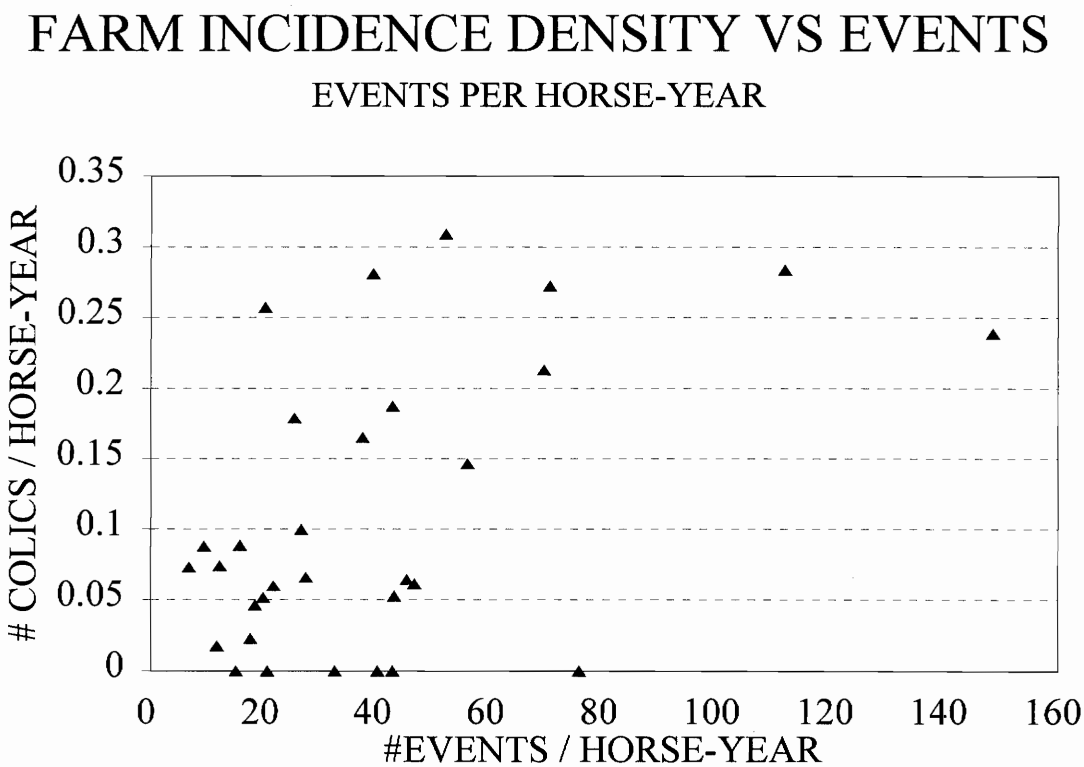

FIGURE 3-1 FARM INCIDENCE DENSITY VERSUS THE NUMBER OF EVENTS PER HORSE-YEAR

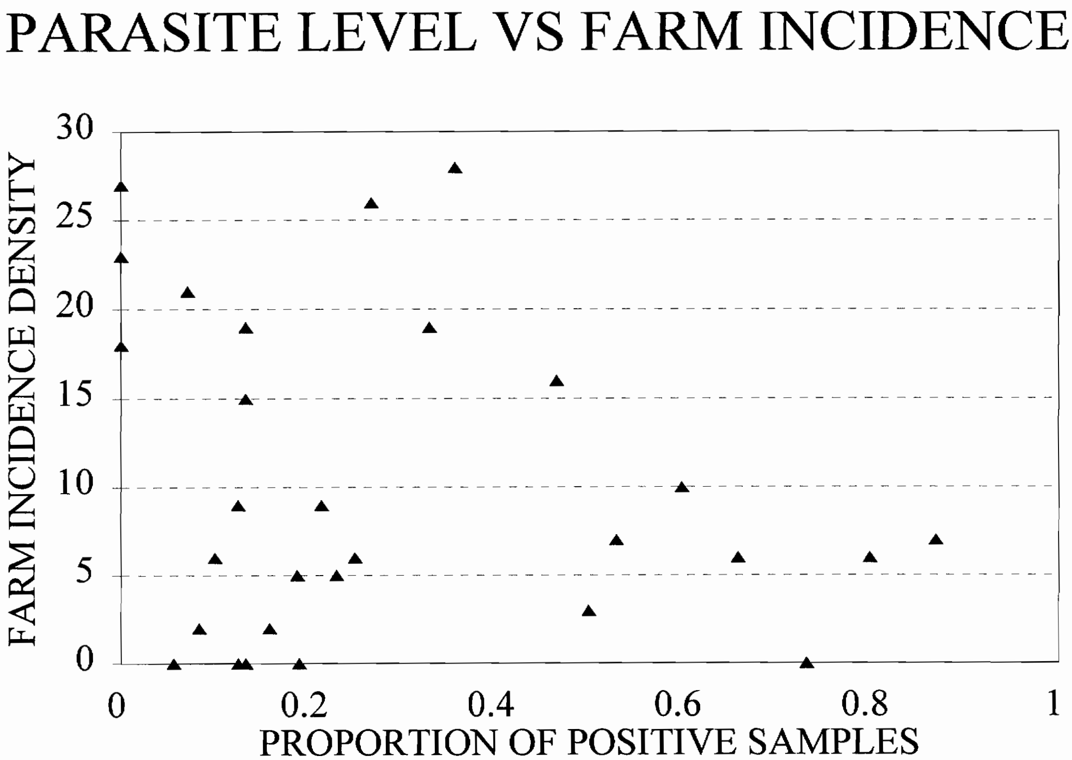

FIGURE 3-2 PARASITE LEVEL VERSUS FARM INCIDENCE DENSITY, colics per 100 horse-years

Chapter 4
A Prospective Study for Equine Colic Incidence and Mortality Rates

Abstract

A one-year prospective study was conducted on horse farms to estimate population based incidence, morbidity and mortality rates of equine colic. Farms with greater than 20 horses and owners willing to participate were enrolled from randomly selected horse owners from two adjacent counties of Virginia and Maryland. Descriptive information for 31 farms with 1427 horses was collected at the initiation of the study and updated at three month intervals. Time on the farm during the study was tabulated for each horse. Colic was reported when a horse was observed exhibiting a behavior indicative of abdominal pain. Horses with colic were visited by investigators within 48 hours to obtain history. The crude yearly incidence of colic was 10.6 colic cases per 100 horse-years, based on 104 cases per 358,991 horse-days. The range for individual farms varied from 0 to 30 colic cases per 100 horse-years, (median=7 per 100 horse-years). A specific diagnosis was not made for 84 (81%) of the colic episodes. Seventy colic episodes (67%) were treated by a veterinarian. Drugs were used in 83 (80%) colic episodes, and 78 (75%) of the colic cases were mild, requiring no treatment or resolving with one treatment. Four horses required surgery. Colic cases were most frequent in the months of December, March and August. Fourteen (13%) horses had more than one episode of colic during the year. Mortality from all causes of death was 2.5 deaths per 100 horse-

years. Seven colic cases were fatal. The proportional mortality rate of colic (28%) was higher than for any other cause of death. Horses less than two years and greater than ten years old had less risk of colic than horses 2-10 years of age. No difference in risk was associated with gender. Arabian horses had the lowest and Thoroughbreds the highest breed specific incidence. Horses used for eventing, or in training had a statistically significant higher risk for colic than adult horses with no use (pets, retired, on pasture with no stated purpose). Horses used for lessons or with no use had the lowest risk of colic.

Introduction

Acute diseases of the equine abdomen with signs of pain are commonly referred to as colic. Many causal factors of colic have been suggested in the literature but the majority of cases are unexplained. Lesions associated with colic have been anatomically and functionally categorized as obstruction, strangulation, non-strangulating infarction, enteritis, peritonitis, ulceration or ileus [3,5,6,7]. Case fatality percentages vary from 6 to 84% depending on the method of disease classification [3,18,25]. The lesion for many colic cases is unknown either because surgery or necropsy was not performed or signs were not definitive enough to make a specific diagnosis or identify the affected anatomic site. The diagnosis for these non-specific types of colic is frequently referred to as ileus, spasmodic colic, verminous arteritis or colic[6].

Incidence of equine colic for randomly selected resident horses on farms is unavailable. The incidence of colic has been reported for several studies with various definitions of the population at risk. Rollins and Clement[15] reported 9% out of 10,541 horses in an Arizona private equine practice had colic over a 5 year period. Bell and Lowe[16] reported an incidence of 27 severe colics in 255,916 horses (4 colics per 100,000 entrant-days) competing in American Horse Shows Association shows. Foreman and White[17] reported 118 (6.1%) colic visits out of 1929 ambulatory calls at the University of Georgia. Barrett et al.[18] using a telephone questionnaire reported 1331 colics treated at 78 Welsh veterinary practices during 1988. The population was estimated as 19,850 equine cases seen during this period. An incidence estimate of 6.7 colic cases per 100 equine visits per year could be calculated from this information. Uhlinger[19] measured an incidence of 26 cases/100 horse-years at risk in a prospective study of 14 non-randomly selected herds. In each of these studies the population at risk was influenced by selection factors.

Colic prevalence estimates are available for several referral or private hospital populations[20,21,22,23]. Cases included are influenced by the practice type, economic and prognostic factors determining which cases are treated at the facility. Most colic studies have been retrospective, and concentrated on defining the relative frequency, diagnostic signs and prognosis of various types of colic. Proudman[24] conducted a prospective survey of colic cases in a British practice but did not include an estimate of the practice population size.

The objective of this study was to estimate incidence and mortality rates and frequency of diagnosis of colic in a randomly selected population of horses. Further I wanted to evaluate the effect of age, gender, breed, horse use and farm type on the risk of developing colic.

Materials and Methods

Case definition-----Colic was broadly defined as any abdominal disease causing a horse to show one or more signs of acute pain (Table 4-1). For the purpose of this study all cases of colic were included with or without a specific diagnosis and cases were not differentiated by pathologic or anatomic characteristics. Colic from non-gastrointestinal lesions was not distinguished from gastrointestinal colic. Colic was considered an acute disease with an induction time of less than two days. Horses were returned to the population at risk after a colic resolved. When colic was diagnosed in a horse that previously had colic during the study, the new episode was included in the study if onset was at least 48 hours after the end of a previous colic episode.

Sampling-----Farms were selected randomly and horses were sampled by cluster sampling by farm, all horses on the selected farm were sampled. A sampling frame of 1367 horse-owners from two adjacent counties, Loudoun County, Virginia and Montgomery County, Maryland, was compiled from equine infectious anemia (EIA) test applications, veterinarian client lists and county extension mailing lists. The counties covered a total land area of approximately 900 square miles just west of Washington DC, and were comprised of a mix of suburban and small community residential areas and farms. A simple random sample of 555 owners was selected from the list frame using computer generated random numbers. Owners were contacted by telephone in order of random selection until 50 farms with 20 or more horses on the farm sometime during the year, were identified. The criteria for farm size was chosen to include farms making management decisions for groups of horses rather than the individual horse. Including farms with 20 or more horses increased the number of horses studied while maintaining a feasible number of farms to be monitored.

Owners or their managers willing to participate were visited by investigators to enroll the farm in the study. Initial information collected included a farm questionnaire and a horse-list. The farm questionnaire included questions on the history, size, type and management of the farm. The horse list contained horse identification, age, gender, breed, use, time lived on the farm, and whether or not the horse had a history of colic in the five years prior to the study.

Colic was defined and the signs listed as part of the initial instructions (Table 4-1). Instructions to the owner included reporting any horse behavior indicative of colic by telephone to the investigators. Farms reporting colic were visited within 48 hours to obtain information about the colic episode and to update changes in the horse list if necessary.

The owner was given a calendar with instructions to record the occurrence of colic, change of horse use, horse movement off and back to the farm, and horse disease, treatment and fatalities. When a horse left the farm the horse was removed from the study during the time it was off the farm and brought back into the study if it returned. Horse days were calculated as a method to determine the number of horses in the study each day and each horse's total time in the study. Each farm was visited every three months to collect the calendars and update the horse records.

To maintain confidentiality, farms were numbered and only the investigators visiting the farms were aware of farm identity. Care was taken not to discuss information about other farms during visits and results were not returned until the study was completed to prevent owners from altering their management practices during the study.

Complete data were collected for one year, with farms entering into the study during a three month period from November, 1990 to January, 1991.

Analysis-----Farm information was entered into Epi Info (Center for Disease Control, Epidemiology Program Office, Atlanta GA), questionnaires and horse data were recorded on Lotus 123 (Lotus Development Corporation, Cambridge MA) spreadsheets. Spreadsheets were imported to dBase IV(Borland International, Scotts

Valley, CA) for sorting, sums, counts and categorical grouping. Descriptive statistics were done using Epi-Info, Lotus 123 or dBase IV software.

Farms were assigned to four categories (breeding, boarding, lessons or training) according to predominant horse use specified by owners. Farm size was determined by the total number of horses on horse list during the year and categorized as less than or greater than 50 horses. A Kruskal-Wallis ANOVA was used to test for differences in the incidence densities between groups of farms.

Horses were assigned to groups based on horse-list description for gender (male, female, castrated male), breed (Thoroughbred, Warmblood, Arabian, Quarterhorse, pony, crossbred (owner identified two breeds or crossbred) and other (American Saddlebred, Tennessee Walking, Andalusian, Morgan, Miniature, Mustang, Draft, Cleveland Bay, Donkey and Appaloosa), age (0-2 years, 2-10 years, >10 years) and use (eventing, racing, training or breaking, showing/show jumping, dressage, hunting, pleasure, lessons, breeding, young (not yet in use), and no use). The no use category includes adult horses described as pets, babysitters, companions, lead ponies, farm horses, retirees, horses resting for rehabilitation, turned-out horses, unbroken horses and two year olds not in training.

Incidence density was computed[151] by dividing the number of colics for a group of interest (numerator) by the total accumulated horse-days for the group of interest (denominator). Incidence densities ratios (IDR) with 95% confidence intervals (CI) for gender, breed categories, age groups, and use groups were computed by the ratio of incidence density of the group of interest to the incidence density of a baseline group. The baseline groups used were gelding for gender, crossbred for breed, 0-2 years for age and no use for use. The number of horses on the study was tabulated for each day and used to estimate incidence density by month.

Colic episodes were classified according to the diagnosis made by the attending veterinarian or called non-specified colic if the diagnosis was not known. Horses that died during the year were classified by cause and the colic proportional mortality rate was calculated.

Seven farm questionnaires were available from farms that dropped out of the study at the beginning. A Fisher's exact test was used to test for differences between participating and non-participating farms for state, farm size, farm type, and horse use categories.

Results

Thirty-one farms (62%) of those initially contacted completed all questionnaires, kept calendars and reported colics. Nine owners declined participation during telephone contact. Of the forty-one farms with enrollment visits, ten failed to complete initial information or decided not to continue at the beginning of the study. During the year three farms ceased operation for financial or personal reasons, these were included in the study up to the time the horses were dispersed.

The initial horse population was 1331 horses. The total horse population including new horses added to farms during the study year was 1427 horses. The characteristics of the farms and horses in the study are summarized in Tables 4-2 and 4-3.

The incidence density for the year was 10.6 colic cases per 100 horse-years, based on 104 colics per 358,991 horse-days (983.5 accumulated horse-years). The incidence density was highest in December, March, and August of the study year (Figure 4-1).

The owners did not report by telephone 34 of the 104 (33%) colic episodes, but noted the signs on the calendars. Description of the signs on the calendar and the treatments provided were used by the investigators to confirm inclusion of report as a colic episode. Multiple signs were reported on 93% (66/70) of colic reports. The frequency of signs reported is listed in Table 4-1.

Eighty-six horses had colic episodes during the study. Seventy-two horses (84%) had 1 colic episode. Fourteen horses (16%) had more than 1 colic episode during the year with 11 of these having 2 colic episodes, 2 horses having 3 colic episodes and 1 horse having 4 colic episodes. The median time between colic episodes was 50.5 days (range 2 to 237 days).

The mortality rate from colic was 0.7 deaths per 100 horse-years. The colic case fatality rate was 6.7% (7/104). One horse was found dead with gastric rupture, one died during treatment and five horses were euthanized due to poor prognosis.

Nineteen colic episodes (18%) were serious requiring treatment more than one time, or causing multiple episodes within 48 hours. Median duration of fatal and serious colics was five hours (range 1 hour to 8 days). Seventy-eight (75%) colic episodes were mild, requiring no treatment or resolving with one treatment. The median duration of mild colics was 1.5 hours (range 0.25 to 24 hours).

Four horses required surgery. Surgical lesions were strangulating lipoma, stomach impaction, large colon torsion and testicular torsion. Two of the four horses were euthanized at surgery.

Twenty-five deaths were reported from all causes (overall mortality rate = 2.5 deaths per 100 horse-years). Twenty eight percent (7/25) of deaths were attributed to colic. The proportion of mortality due to colic was greater than the proportion for any other cause of death in this population including old age or injury (Figure 2). In the 2-10 year age group, 43% (3/7) of deaths were due to colic.

A specific diagnosis was not made for 84 (81%) of the 104 colic episodes. Colics which were diagnosed based on signs, surgery, or necropsy included 9 obstruction-impactions, 3 strangulation-obstructions, 4 gas or spasmodic colics, 2 gastric ruptures, 1 enteritis and 1 testicular torsion.

Treatment was administered by a veterinarian or owner in 88 of 104 (85%) colic episodes. For the 103 cases observed by the owners, excluding the horse found dead, 15 (14%) had no reported treatment, 18 (17%) received drugs without examination by a veterinarian, 5 (5%) were examined by a veterinarian and no drug therapy was reported, and 65 (63%) received drugs and were examined by a veterinarian. The most frequent medications used were flunixin meglumine (67), dipyrone (36), mineral oil (28), xylazine (20) and butorphanol tartrate (16). Other treatments reported included phenylbutazone (6), acepromazine (5), oral antacids (2), penicillin (2), tetracycline (2), trimethroprim sulfa (2), Dr. Bell's Veterinary Medical Wonder (2) (belladonna, Dr. Bell's Veterinary Medical Co, Kingston, Ontario, Canada), detomidine (1), ranitidine (1), charcoal (1), Red Cell (1) (vitamin-iron-mineral supplement, Horse Health Products, Mundelein, IL), magnesium sulfate (1), milk of magnesia (1), gentamicin sulfate (1), dexamethasone (1), psyllium (1), heparin (1), natural herbs (1) and Probiocin (1) (microbial products, Pioneer, Johnston, IA).

The size of the horse population on the farms ranged from 17 to 98 horses. Farm specific incidence density ranged from 0 to 30 colic cases per 100 horse-years (median = 7) (Figure 4-3). Two thirds (20) of the farms had farm specific colic incidence less than the overall study incidence. Seven farms (23%) had farm specific incidence more than twice the overall study incidence.

Specific incidence density and incidence density ratios for farm and horse characteristics are shown in Tables 4-2 and 4-3 and Figures 4-4, 4-5, and 4-6.

The farm type specific incidence density in cases per 100 horse-years was 12.9 for training farms, 14.7 for boarding farms, 8.4 for breeding farms and 6.7 for farms giving lessons. The difference between farm types was not statistically significant (p=0.41).

Gender specific incidence density in cases per 100 horse-years was 10.3 for females, 11.5 for geldings and 8.2 for males. No statistically significant differences in risk was associated with gender; female relative to gelding, IDR=0.9 (95%CI=0.6-1.3); male relative to gelding, IDR=0.7 (95%CI=0.4-1.5).

The age group with lowest risk was horses less than two years old. Horses 2-10 years old had significantly greater risk for colic than horses less than two years old, IDR=3.1 (95%CI=1.7-5.8). Horses greater than 10 years of age did not have significantly increased risk, IDR=1.6 (95%CI=0.7-3.4) relative to horses less than two years old.

The lowest breed specific colic incidence was in the Arabian horses , ID=3.2 cases per 100 horse-years (Figure 5). Thoroughbred horses had the highest risk, ID=12.6 cases per 100 horse-years. If crossbred horses, ID=5.4 cases per 100 horse-years, were used as a comparison group, Thoroughbreds had a marginally significant increase in risk, IDR=2.3 (95%CI=1.0-5.2). No other group had a significant difference in risk from crossbreds.

Horses used for eventing IDR=3.6 (95% CI=1.4-9.5) or in training, IDR=3.5 (95%CI=1.2-10.1) had a significantly higher risk for colic when compared to adult horses with no use (Figure 6). The incidence density of horses with other uses were not statistically different than the incidence density of adult horses with no use. Horses used for lessons or with no use, either adult or growing horses (foal, weanling and yearlings), had the lowest risk of colic.

Comparison analysis between participating and non-participating farms showed that the drop-out farms were significantly more likely to have horses used for hunting than farms that participated in the study ($p=0.03$). Other comparisons were not significant.

Discussion

Incidence rates are not available for most veterinary diseases because information about the population at risk is often unavailable even if a reasonable count of diseased animals is known. To estimate the incidence of a disease in a population, enough individuals must be included in a defined cohort to assure that an adequate number of disease episodes will occur during the observation period [151].

Incidence estimated in this study using a randomly selected sample of farms should be free of selection bias due to exposure or disease status. Horse owners may have missed being identified if they never used veterinarians, never required EIA tests or had no contact with extension agents. It is unlikely that any farm in the study area with greater than 20 horses was missed.

A possible selection bias was owner willingness to participate. Participation was 62%. Collection of data required a large commitment of owner/manager time over one year. The reasons given by owners for refusing to participate were: too busy, too much bother or did not wish to participate. Management of a farm may be affected by a busy owner or willingness to participate. It was assumed that some owners did not wish to participate because they considered the study to invade their privacy. Owners with history of colic on their farms might have been more inclined to participate if they expected to benefit, however care was taken to outline study benefits in broad terms of future recommendations for all horse farms. Analysis of drop-outs showed that farms with horses used for hunting were more likely to decide not to participate after starting. The significance of this is unknown, but may have resulted in hunters being under represented in our study population compared to the true horse population for these two counties.

Colic includes a diverse group of abdominal pathological conditions involving the gastrointestinal tract and other organs. Since the anatomic location of the problem is often unknown [3], all cases meeting the case definition were counted including the case known not to involve the gastrointestinal tract, a testicular torsion. Serious colic was most likely counted since owner cooperation was good and all owners expressed a knowledge of recognizing colic in the past. Colics of short duration especially those occurring while the animal was out on pasture, in an unattended stable or at night might have been missed.

Some owners did not consider some mild signs of colic important enough to notify the research team, but recorded the colic event on the calendar. Owners were given written instructions for reporting colic and investigators visited farms to confirm colic information to improve accuracy of the data. Uncooperative owners removed themselves from the study during the initial phase by not completing startup questionnaires.

In other studies, the time contribution of horses is unknown; horses present in the study population for a short time are treated the same as horses continuously present during the study time. The number of horses which never have veterinary care or are treated by other veterinarians is unknown and they are not included in the population at risk. Studies using practice populations may have incomplete case reporting if either cases or controls received treatment from other sources. Differential reporting bias may occur if controls are followed differently than cases.

This study comes closest to estimating colic incidence in a general horse population compared to other studies because of the selection process used to establish the cohort, the determination of horse-days at risk and the large number of farms and horses included. The criteria defining the study population influence how the results can be applied to other populations. This study reports incidence on farms with greater than 20 horses in the mid-Atlantic region of the United States. The population was predominantly Thoroughbred and horse uses were varied. The incidence and risks identified may not apply to other populations.

The colic incidence is similar to several studies including Rollins and Clement[15], but lower than reported by Uhlinger[19,42] in studies examining parasite control and methods of estimating incidence of field colics. In the other studies where only individual horses were identified there is no way to compare the farms to those in the present study.

Previous studies have implicated females as having a higher incidence of colic because of increased risk during and after pregnancy [118,178]. No association of gender or use as a breeding animal to colic was found in this study. Since some of the mares used for breeding left the farm just before or just after foaling it may be that colic occurred when the mares were away from the farm.

The decreased risk of colic associated with horses in the 0-2 year age group compared to older horses remains unexplained. The increased risk of the 2-10 year but not in the older group (>10 years) when compared only to the young horses was investigated further in another portion of the study (Chapter 5).

Arabian horses and Standardbred horses have previously been reported to have a significantly higher incidence of colic[25,131,132,146]. These results were not based on a population study and are not supported by this study. The Arabian breed in this study had less colic than other breed categories. I hypothesize this may have been related to the type of work or use of these horses. Only 4 of 50 Arabians were involved in training or eventing, the uses with the highest risk. There were too few Standardbreds in this population to evaluate risk for this breed.

Age, gender, and breed should be highly related to other use, farm, and management factors. The association of colic risk to these factors need to be evaluated controlling for these other factors.

In conclusion, the colic incidence density measured for this population was 10.6 colic cases per 100 horse-years. The majority (75%) of equine colic episodes were associated with mild clinical signs and nearly one-fifth (19%) were not given any treatment. However the proportional mortality rate for colic was the highest among causes of death including old age and injury such as fracture. Horses which are used for strenuous activities such as eventing and training had the highest risk for colic compared to horses with less strenuous uses. Young horses appeared to be protected from colic compared to other ages and young adult horses appeared at higher risk.

TABLE 4-1 FREQUENCY OF COLIC SIGNS

The owners were instructed to identify colic by the following signs. Signs were recorded for 70/104 (67%) of colics, signs were unavailable for 30/104 of colics.

	#horses (%of reports)
Rolling	31 (44%)
Continuous or intermittent pawing	30 (43%)
Lying down for excessive periods of time	20 (29%)
Lying down repeatedly	15 (21%)
Turning head toward flank	10 (14%)
Repeatedly curling the upper lip	9 (13%)
Backing into corner, uncomfortable	7 (10%)
Kicking at abdomen	5 (7%)
Standing in a stretched position	3 (4%)
Frequent positioning as if to urinate	2 (3%)
Lack of defecation greater than 24 hours	1 (1%)
Bloat	0 (0%)
Lying on back	0 (0%)
Circling as if wanting to lie down	0 (0%)

Other signs reported that were not included in the case definition given to owners: Lack of appetite 26(37%), Other strange behavior 6(9%), Depressed 5(7%), Painful 5(7%), Sweating 5(7%) and Diarrhea 4(6%).

TABLE 4-2 FARM DESCRIPTION AND COLIC INCIDENCE DENSITY (ID)
(n=31 farms, cases per 100 horse-years)

Characteristic		#farms(%)	ID
Size	17-50 horses	18(58%)	14.5
	>50 horses	13(42%)	8.0
Type	Breeding	12(39%)	8.4
	Training	5(16%)	12.9
	Boarding	9(29%)	14.7
	Lessons	5(16%)	6.7

TABLE 4-3 DESCRIPTION OF HORSE POPULATION

Colic incidence density (ID) and incidence density ratio (IDR) for horse characteristics relative to baseline category (n=1427 horses, cases per 100 horse-years)

* 95% CI does not include 1

Characteristic		#horses(%)	ID	IDR(95%CI)
Gender	Gelding	618(43%)	11.5	1.0
	Male	181(13%)	8.2	0.7(0.6-1.3)
	Female	628(44%)	10.3	0.9(0.6-1.3)
Breed	Crossbred	160(11%)	5.5	1.0
	Arab	50(4%)	3.2	0.6(0.1-4.9)
	Quarterhorse	68(5%)	4.2	0.8(0.2-3.8)
	Pony	77(5%)	7.8	1.4(0.4-5.1)
	Other	70(5%)	8.1	1.5(0.4-5.3)
	Warmblood	110(8%)	12.4	2.3(0.8-6.3)
	Thoroughbred	892(63%)	12.6	2.3(1.0-5.2)
Age	Born 1989-1991	338(24%)	4.6	1.0
	Born 1979-1988	781(55%)	14.5	3.1(1.7-5.8)*
	Born <1979	308(22%)	7.4	1.6(0.7-3.4)
Use	Adult, No Use	112(8%)	6.7	1.0
	Lessons	88(6%)	1.6	0.2(0.0-1.7)
	Young, Not yet in Use	227(16%)	3.2	0.5(0.1-1.6)
	Hunt	101(7%)	6.6	1.0(0.3-3.4)

Characteristic		#horses(%)	ID	IDR(95%CI)
Use, continued	Pleasure	162(11%)	10.4	1.6(0.6-4.4)
	Breeding	222(16%)	11.7	1.8(0.7-4.6)
	Dressage	109(8%)	14.0	2.1(0.7-5.9)
	Show	123(9%)	14.4	2.2(0.8-6.0)
	Race	138(10%)	15.4	2.3(0.8-6.4)
	Training	69(5%)	23.6	3.5(1.2-10.1)*
	Event	76(5%)	24.0	3.6(1.4-9.5)*

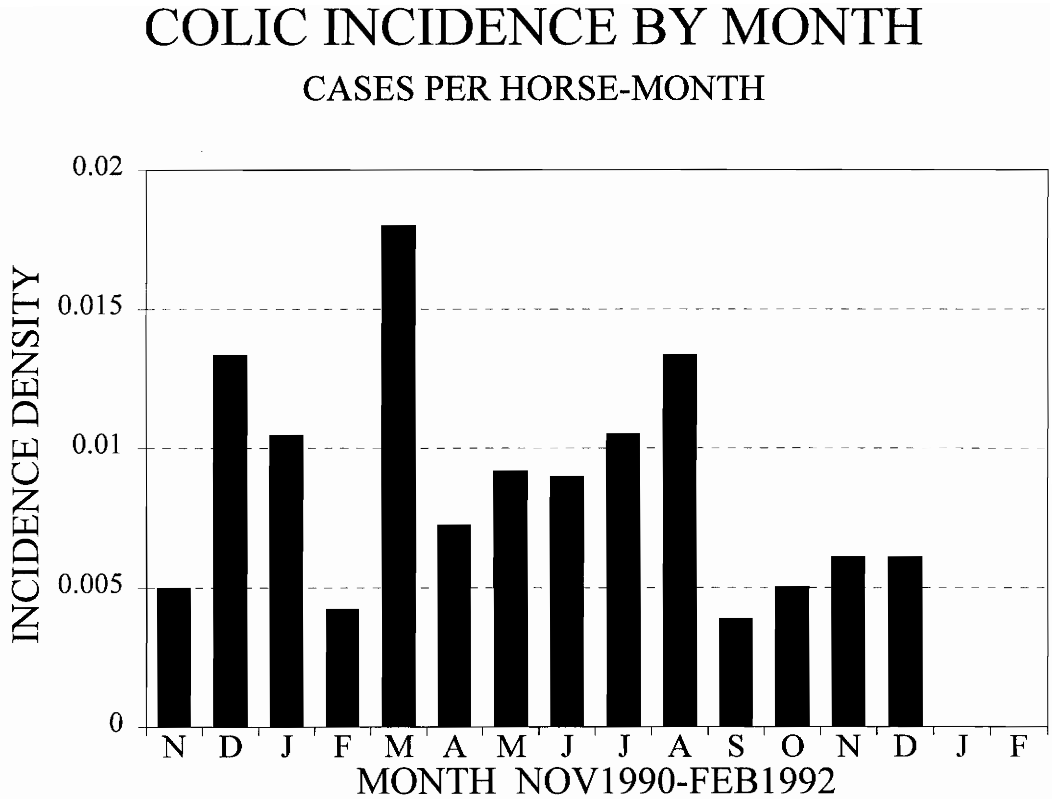

FIGURE 4-1 COLIC INCIDENCE BY MONTH, cases per horse-month.

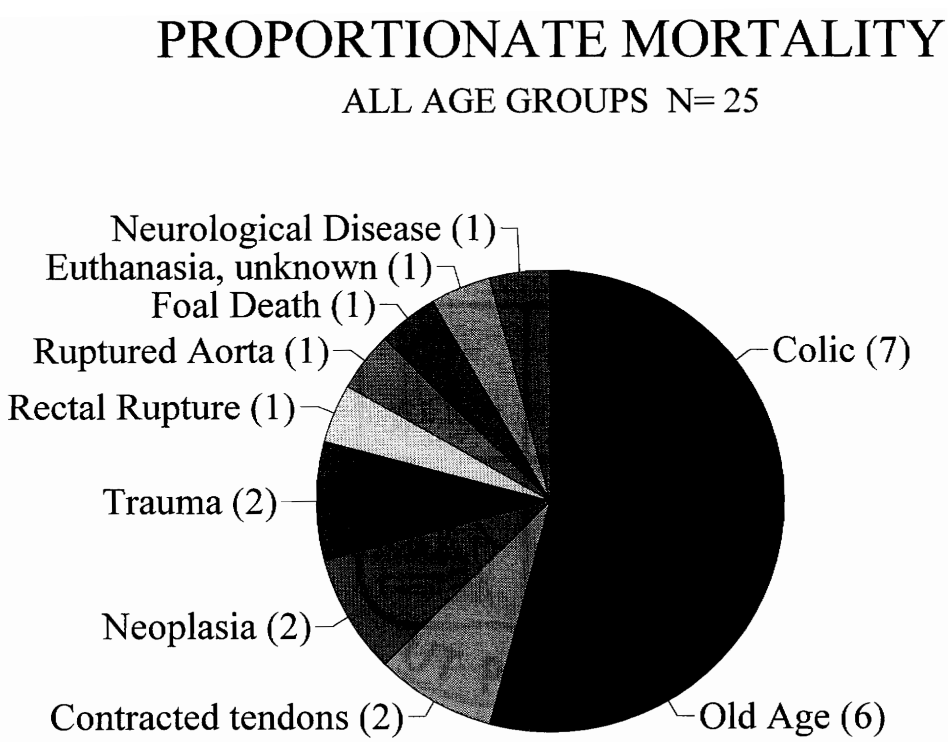

FIGURE 4-2 PROPORTIONAL MORTALITY.

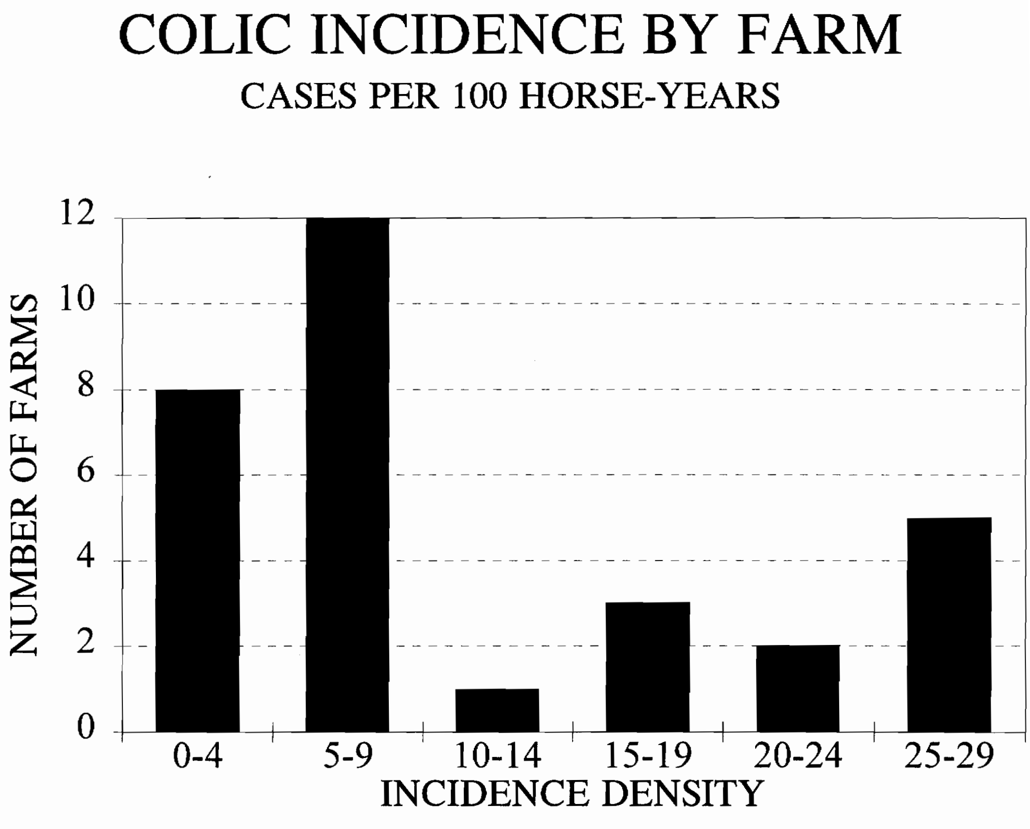

FIGURE 4-3 COLIC INCIDENCE BY FARM.

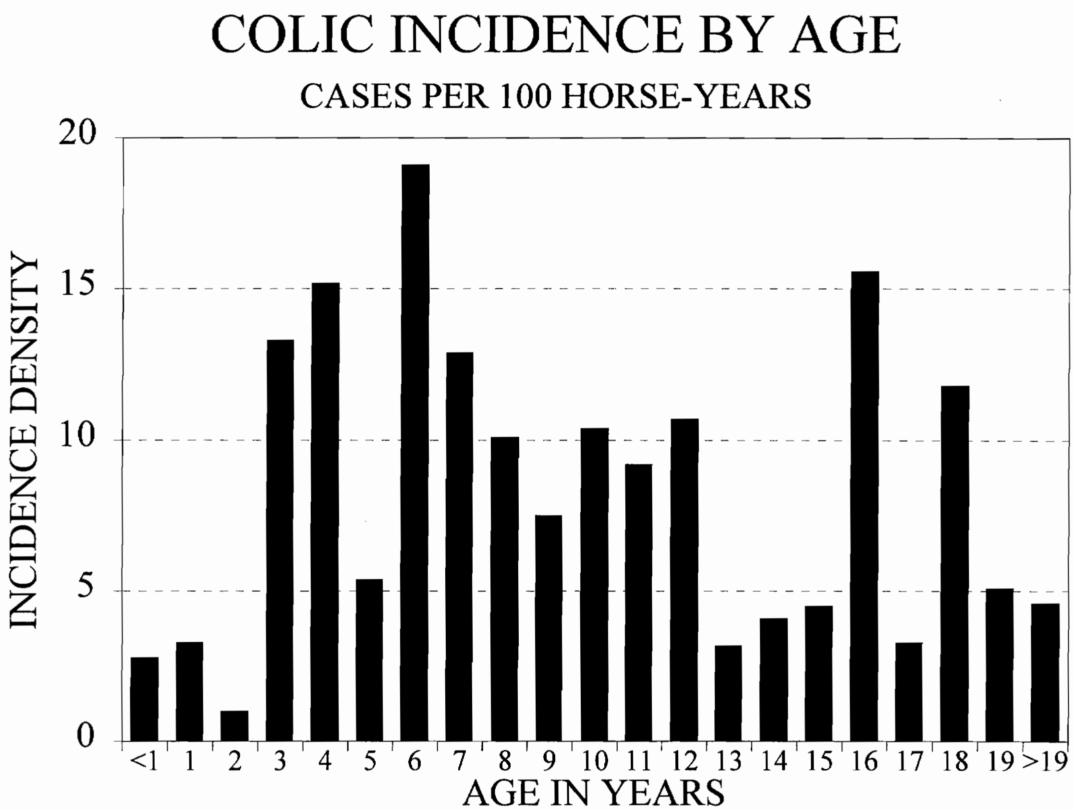

FIGURE 4-4 COLIC INCIDENCE BY AGE.

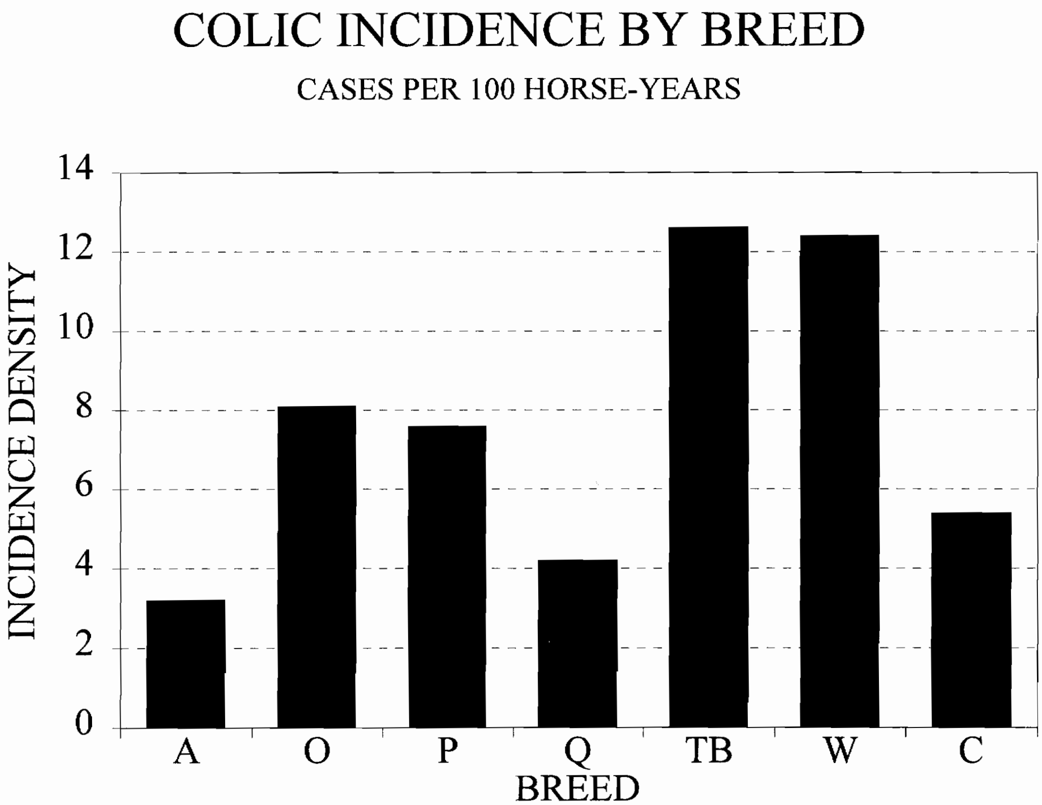

FIGURE 4-5 COLIC INCIDENCE BY BREED.

Breed groups: A=Arabian, O=Other (American Saddlebred, Tennessee Walking, Morgan, Appaloosa, Miniature, Mustang, Draft, Cleveland Bay, Donkey or Andalusian), P=Pony, Q=Quarterhorse, TB=Thoroughbred, W=Warmblood, C=Crossbreed.

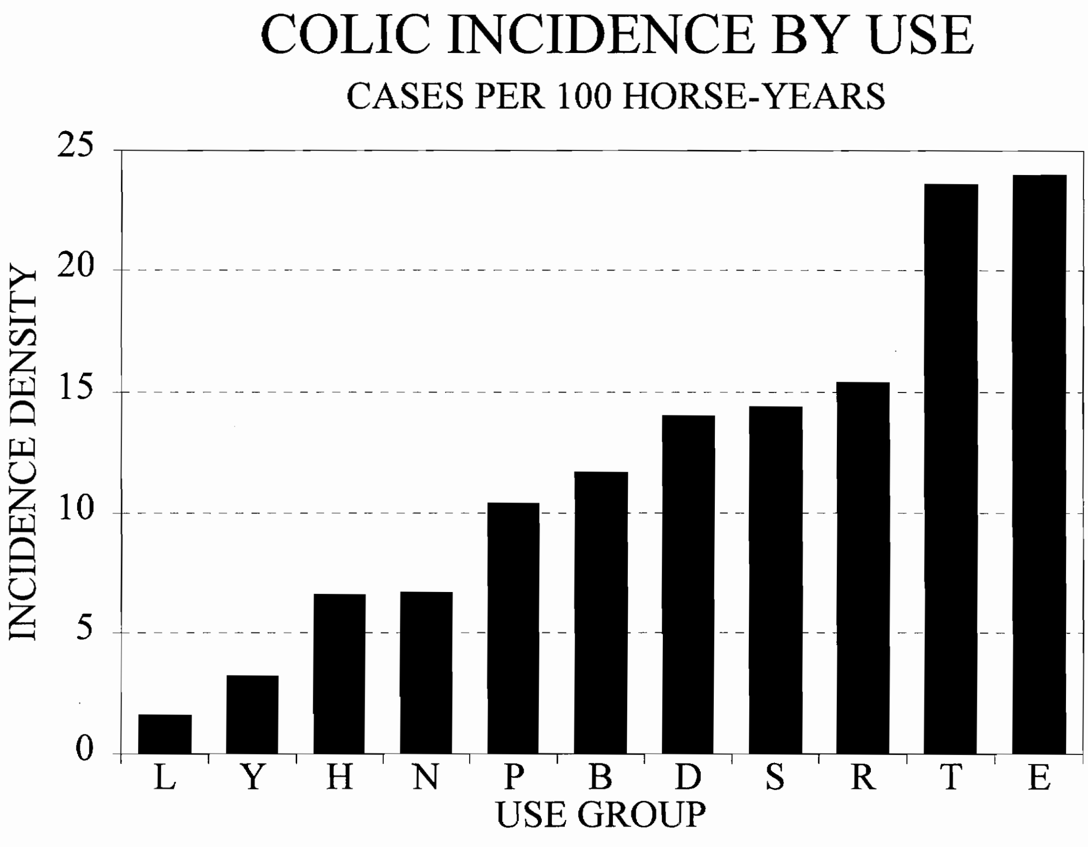

FIGURE 4-6 COLIC INCIDENCE BY USE.

Groups: L=Lessons, Y=Young (Foal, Weanling, or Yearling), H=Hunt, N=No use (Adult), P=Pleasure, B=Breeding, D=Dressage, S=Show, R=Racing, T=Training, E=Event.

Chapter 5

A Farm-based Prospective Study for Equine Colic Risk Factors

Abstract

A one-year prospective study was conducted on horse farms to identify risk factors for equine colic. Farms with greater than 20 horses and owners willing to participate were enrolled from randomly selected horse owners from two adjacent counties of Virginia and Maryland, USA. Farm and individual horse historical and current management, nutrition, exercise, use and health practices were recorded using a questionnaire for 31 farms with 1427 horses. Owners kept calendars to record occurrence of specified events and any changes in the original information for any horse. Feeds were analyzed for nutrient content. Farms were visited every three months to update information. Colic was reported by the owner when a horse was observed exhibiting a behavior indicative of abdominal pain. Farms were visited to obtain information about the horse with colic within 48 hours of the episode. Time on the farm was tabulated for each horse. The estimated yearly incidence of colic was 10.6 colic cases per 100 horse-years.

Farms and horses were classified into risk factor categories (farm management, horse characteristics, housing and pasture management, use related management, nutritional management, health related management and events) and screened by univariate statistical tests to select variables for multivariable analysis. Variables selected in the screening step were analyzed by stepwise forward logistic

regression to allow control of possible confounding factors. Analysis was conducted at two levels; the farm and the horse-level with farm as a random effects variable, using a p< =0.05 level of significance. No variables were significant in the farm level logistic regression. Significant horse variables were 1) age 2-10 years, Odds ratio (OR)=2.8 (95% confidence interval, 1.2-6.5); 2) history of previous colic, OR=3.6 (1.9-6.8); 3) changes in concentrate feeding during the year OR=3.6 (1.6-5.4), 4) more than one change in hay feeding during the year OR=2.1 (1.2-3.8), 5) feeding high levels of concentrate (>2.5 kg/day dry matter, OR= 4.8 (1.4-16), >5 kg/day dry matter, OR=6.3 (1.8-22)) and 6) vaccination with monocytic ehrlichiosis (PHF) vaccine during the study, OR=2.0 (1.8-22). Feeding a whole grain with or without other concentrate components had less risk than concentrate diet without whole grain included. If variables related to concentrate feeding frequency or concentrate type were substituted for the concentrate level variable in the analysis, the significance of the variables was reduced but the analysis remained statistically significant and other variables were unchanged. Nutritional factors relating to changes in feed and the amount and type of concentrate were all strong risk factors for colic. The risk for PHF vaccination was thought to be representative of the health events and management factors for the farm, rather than related to the vaccine itself. Risk for horses age 2 to 10 years is thought also to be related to use, nutrition and management factors. The results of this study suggest that diet and change in diet are important risks for colic in a population of horses on farms.

Introduction

Many causes have been suggested for equine colic, but only a few risk factors are supported by strong evidence and are widely accepted. Parasites such as *Strongylus vulgaris* have historically been reported as the cause of a large proportion of colic cases and experimental studies have documented gastrointestinal lesions due to these agents[32,34,35,36,37,38,39]. Other studies have implicated small strongyles[42,44,45], tapeworms[47,48,49,50,51,52], and ascarids[55,56] as causes of colic. Foreign materials have been demonstrated in the intestinal tract associated with impactions and enteroliths in a number of case reports and case series. Sand impaction[15,58,59,124], obstruction due to hair[60,61], paper bag[62], cloth, rope or twine[63], wood[64], rubber fencing[66], or enteroliths formed around a metal or stone nidus[67,113] have been reported. Colic has been associated with ingestion of certain toxic plant materials such as black walnut bedding[69], cockspur hawthorn[70], acorns[71], castor beans, ragworts or oleander[72], insects such as blister beetles[73] or drugs such as amitraz[74,75] or atropine[76]. Colic has been observed in cases of colitis due to infectious agents including Salmonella[77], *Ehrlichia risticii*[78] and Clostridium[79]. Strangulations of portions of the intestine have been associated with congenital or acquired anatomic defects,[82] such as mesodiverticular bands[80] or Merkel's diverticulum[81], aganglionosis[83] or with neoplasms such as lipoma[93,94] and lymphosarcoma[95]. Trauma has indirectly been implicated in causing mesenteric rents or internal hernias[84,86] which result in incarceration of bowel.

Nutritional risk factors proposed in the literature are feeding a diet with an imbalance of roughage to concentrate[112,113], feeding certain foodstuffs such as coastal Bermuda grass[114,115,116], spoiled feed[31]), young protein-rich grass[117,118], coarse, poor quality roughage[114,119,120], pelleted feeds[23], or cubes[121]; over-feeding[31], underfeeding[15,32] and feeding on the ground[123,124]. Other risk factors mentioned are inadequate water supply[116,125], changes in bedding[120], weather changes[15,128], poor dentition[126], recent pregnancy[20,130] or previous colic[7,98,127]. These reports are anecdotal or based on observations of case populations without comparable normal control populations.

Reports that consider the role of management factors in colic are rare. Two recent case control studies examined risk factors associated with management using multivariable analysis[131,132]. Both concluded that diet, changes in activity and the Arabian breed were risk factors for colic. In most other studies, management factors were analyzed by comparing case populations diagnosed with different types of colic, rather than with healthy horses or horses without gastrointestinal disease. Variables in these studies were evaluated individually without attempting to control for confounding factors.

This report includes results from a prospective study of horses from a random sample of mid to large size horse farms in Virginia and Maryland, USA. In the first part of the analysis incidence and mortality rates were determined (Chapter 4). Data from the same farms and horse cohort were also collected to determine risk factors for colic. Specific factors hypothesized to increase colic were decreased roughage intake, transport, recent pregnancy, decreased water intake, parasite infection, high concentrate consumption, and high level of medical treatment. The objective of this part of the study was to determine if the above factors, other farm or horse factors, nutritional or management practices were associated with an increased risk of colic in horses or on farms in the study.

Materials and Methods

Data collection and categorization-----The case definition, study population, study design and case follow-up are described in the report on incidence of colic using the same farms and horse population (Chapter 4). At the initiation of the study, owners or their farm managers willing to participate were visited by investigators to be enrolled in the study. Initial information collected were a farm history questionnaire, horse-list, individual horse management profiles, farm map, and samples of all feeds. The horse-list contained horse identification, age, gender, breed, use, time on the farm, and whether the horse had a history of colic within the last five years. Categories selected for analysis are listed in tables 5-1 to 5-6. Descriptions of categories developed from open-ended questions are included in the following paragraphs.

The owner/manager was given a calendar with instructions to record the occurrence of specified events or any changes in the profile information for any horse. Each farm was visited every three months to collect the calendars, update the horse-lists, profile new horses and sample new types of feed. Pastures were sampled on each farm once during the spring, summer and fall. Fecal samples were collected from 5 horses on each farm during the spring, summer and fall.

The number of parasite eggs per gram of fecal sample were counted by the McMaster's method[176]. The proportion of positive fecal samples (>0 eggs per gram) was determined for each farm.

Nutrients were determined for the feed and pasture samples at the Forage Testing Laboratory, Virginia Tech, Blacksburg, VA. Farms were ranked by crude protein and digestible energy for pasture for each season. Spring, summer and fall samplings were rated as high or low for protein or energy based on whether or not the farm ranked above or below the median value of all farms in that season. Protein and digestible energy for hay samples were handled similarly. If multiple samplings were available from a farm, a mean farm value was used to assign the high or low ranking.

Nutritional variables were defined based on each horse's diet from the original profile information recorded when the horse entered the study. Horses in the study were classified into one of seven diet groups based on feedstuffs reported on the profile: 1) pasture only, 2) pasture and hay, 3) pasture and concentrate, 4) pasture, hay and concentrate, 5) hay and concentrate, or 6) hay only. Since no colic episodes occurred in diet groups 1 (pasture only) and 6 (hay only), a forage only diet group was formed from groups receiving no concentrate (1, 2, and 6). Young horses (foals, weanlings, and yearlings) were classified as a separate group because their diet was changing as they grew older. For other variables in this analysis of all horses, no adjustment was made for young horses.

Concentrates were classified by investigators from the brand name or description provided by the owner as 1) commercial pellet, 2) commercial or custom sweetfeed, 3) mixture (either called a mix by the owner or being fed a combination of pellet and sweetfeed and/or other components), or 4) whole grain such as oats or barley. Horses were categorized into mutually exclusive groups by the concentrate type received. A second categorization of the horses receiving a mixed feed placed horses into non-mutually exclusive groups based on whether they received pelleted feed or sweetfeed or whole grain as a component of their diet. The pellet category in this case included horses with pellet as a component of the diet either as the only concentrate fed or part of a mixture.

A full unit of delivery of concentrate (can, quart, bucket, etc.) was weighed for each feed sample. Using the feed analysis, dry matter intake of concentrates was calculated from the amount fed for each concentrate (number of units fed per day x weight of one unit x dry weight percentage). If dietary analysis was unavailable, nutritional information for a feedstuff was estimated from an average of similar feedstuffs analyzed in the study (for example bran analysis was available from all but one farm; the average value was used for the missing farm) or values from National

Research Council's Nutrient Requirements of Horses[175] were used. Crude protein and digestible energy intake of concentrate were computed from the dry matter intake. These values were summed for every concentrate reported in the diet for each horse to obtain a total daily concentrate dry matter, protein and digestible energy intake for each horse. Intake values were ranked and four levels determined for classification of horses; none, low, middle and high intake by approximate terciles for each nutrient parameter.

Sequence of feeding of concentrate, hay and water was reported by the owner and categories assigned on the basis of the first component fed. If the concentrate and hay were fed together, the horse was classified as all; if the order varied between feeding times, the horse was classified as variable; or if the horse received only one component at a feeding or consumed only pasture, it was classified as no order.

Hays were classified as alfalfa, timothy, orchard grass or mixed grass by investigators from the owner description. Pastures were classified as clover, orchard grass, mixed grass, grass and weeds, or dirt. Owner description of hay intake on the profiles was either free-choice or in some measurement of pounds, flakes or bales. A reliable numerical estimate of hay intake was not possible without better defined measures. Hay intake was classified either free choice, measured or no hay.

Other nutritional classifications included whether horses received a daily vitamin-mineral or commercial supplement in addition to a plain or trace-mineralized salt block; if they received additional feedstuffs besides concentrate (such as bran, beet pulp, corncobs, corn oil, calf manna, linseed meal, or soybean meal); if they received a daily treat (such as apples, carrots, sugar or candy); or, if they received a medication in their daily diet. The total number of additives a horse received besides concentrate were counted. Profile and calendar entries were used to classify horses as being fed bran daily, infrequently (weekly or occasionally), or not at all.

History variables were based on the most recent date for events reported on the horse's profile prior to the beginning of data collection. Since foals born in 1991 would have no opportunity to have a history of any problem and would distort the "none" category, they were excluded from the population used for these calculations.

Calendar entries were classified by the investigators according to major events such as treatment, veterinarian visit, transport, parasite control, vaccination, farrier visit, breeding, foaling, disease (lameness, depression, diarrhea, respiratory infection, colic, fever, or injury), management alteration or unusual event; or changes from the original profile such as nutrition or exercise changes. The number of events or changes during the year in each category was tabulated for each horse and used to assign the horse into frequency categories; none, low, and high. Nutrition events were subclassified as changes involving concentrate, hay, bran or additive. Events referring to a treat such as apples were excluded because they were too numerous and appeared inconsistent between horses. Management events were further classified as a 1) stable, pasture or paddock change, 2) routine horse care such as clipping, weighing, pulling mane, or bathing, 3) farm maintenance such as using fly spray, liming fields, or changing bedding, 4) breeding-related event such as starting lights, or 5) problem, non-routine, or unusual event such as a horse show, snowstorm, or broken gate.

Calendar health entries were further classified by type, body system, time, and diagnosis. Colic related treatments and veterinary visits were omitted from event categories. Treatments and veterinary visits were categorized as 1) drug, 2) therapy (such as massage, hose, or wrap), 3) routine care (such as Coggins test, dentistry, prepurchase examination, or reproductive palpation), 4) diagnostic (examination, laboratory tests or radiographs for a specific problem), or 5) surgery (such as castration or suturing). Days of treatment were totalled for categories 1 and 2. Body system was assigned for each treatment, veterinary visit or health event. A descriptive diagnosis was assigned for each problem being treated based on calendar entries. Problems often had multiple entries if treated for several weeks and seen several times by a veterinarian. Since reasons for all events were not always included, if more than seven days had elapsed between treatments or visits, two events were considered different problems. Treatments with phenylbutazone or steroids without a stated reason were classified as non-specific inflammation. Other events without a specified reason were classified as unknown. Total number of health problems and number of different problems for the year were counted for each horse.

Horses were classified by the anthelmintic used for parasite control during the year: 1) ivermectin only, 2) other product only, 3) ivermectin and another product or 4.) none. The number of anthelmintic administrations were counted for each horse.

Horses were classified on whether or not they received one or more vaccinations during the study. They were also classified according to individual vaccinations received including tetanus, encephalomyelitis, rabies, rhinopneumonitis, influenza, monocytic ehrlichiosis (PHF), strangles, or other diseases (botulism or rotavirus).

Horses were classified on whether or not they entered the study after the initiation date for their farm, left the farm before the end of the study or had multiple starting dates indicating they had left and returned to their farm.

Because the horse population was dynamic, total horse days on the study were tabulated for each horse to allow for computation of incidence density based on the actual time the horse was under surveillance for colic during the study year. Cases of colic were tabulated and reviewed by the investigators to confirm that each case met the case definition. Complete data were collected for one year on each farm, with farms starting staggered from November, 1990 to January, 1991 and completing between November, 1991 and February, 1992.

Analysis-----Farm history information was entered into Epi-Info questionnaires (Center for Disease Control, Epidemiology Program Office, Atlanta, GA) and horse data were recorded on Lotus 123 (Lotus Development Corporation, Cambridge, MA) spreadsheets. Spreadsheets were imported to dBase (Borland International, Scotts Valley, CA) for sorting, sums, counts and categorical grouping. Risk factors were analyzed at both the farm level and at the horse level.

Risk factors were screened as explanatory variables by univariate statistical tests. A Kruskal-Wallis ANOVA was used to test for differences between the incidence density of farms in different exposure categories. Factors with a p value $<=0.25$ for a difference between categories were selected for inclusion in a farm level logistic regression analysis.

Variables selected at the farm level were tested as explanatory variables for high colic incidence on the farm in a stepwise forward logistic regression using EGRET (Statistics and Epidemiology Research Corporation, SERC, Seattle, WA). A farm was classified a high incidence farm if it was in the top third of all farms ranked according to farm specific incidence densities (ID $>$ 0.1, n=11). A farm was classified as a low incidence farm if it was in the lower two thirds of farms ranked according to farm specific incidence density (ID $<=$ 0.1, n=20). A p-value $<=0.05$ was used as the criteria for logistic regression.

For horse-level variables, the incidence density ratio (IDR), defined as the incidence density of the exposed group divided by the incidence density of the unexposed group, was used to determine if a variable posed a significant risk for colic[151]. Incidence density (ID) for each exposure category of a variable was computed from the number of colic cases experienced by horses in the category divided by the total horse days accumulated by the horses belonging to the category. A baseline exposure category was selected for each variable. The ratio (IDR) of the exposure category ID relative to the baseline category ID was computed with its confidence interval (CI). Each IDR was tested for difference from 1 by a z-test with the corresponding p-value determined. A variable with an IDR with $p <= 0.1$ was selected for inclusion in a horse level logistic regression.

Variables selected at the horse level were tested as explanatory variables for presence of colic in a random effects forward stepwise logistic regression. Farm, age, breed, use, concentrate intake, and stall time were identified a priori as possible confounders. Farm was used as the random effects variable. The variable with the lowest p-value was selected at each step as the variable that most improved the analysis until no additional variables could be added that significantly improved the analysis ($p <= 0.05$). Farm variables selected by univariate testing were checked for significance in the final horse random effects logistic regression analysis. Odds ratios and confidence intervals for the total population were computed based on the best fitting analysis.

The contribution of farm as a random effect was tested by comparing the final analysis with the random effect term (%SCL) to the analysis without the term. The significance of the difference was determined from the square root of the likelihood ratio statistic against a one-tailed normal distribution.

Two models were developed, one using the first reported colic for each horse (86) and one using all reported colic cases (104). Population size for the first colic analysis was 1427. To use all colics, a horse that had multiple colic episodes was re-entered into the study as a new horse, making the population size 1445.

A potential bias of concern was if farms reporting more events overall also reported more colic, than farms that reported fewer events. To assess the strength of this relationship, a Spearman's correlation coefficient was computed between the farm specific colic incidence density and the total number of events per horse year reported on the farm.

Results

Incidence density for first colic was 9.1 colic cases per 100 horse-years, based on 86 colics per 346,151 horse days (948 accumulated horse-years) (Chapter 4). The crude incidence density for all colics was 10.6 colic cases per 100 horse-years, based on 104 colics per 358,991 horse days (984 accumulated horse years).

The results of the farm factor univariate analysis are shown in Table 5-1. No variables were selected in the farm level logistic regression.

The correlation between number of all types of events reported by a farm and the farm specific incidence density was 0.50. Farms ranged from 6.8 to 148.7 events per horse-year reported (Median = 39.5/horse-year). All 31 farms reported at least one nutrition, veterinary visit, vaccination, transport, farrier visit, and parasite control event during the year. One or more treatment events were reported by 30 farms, management events by 29 farms, breeding events by 12 farms, colic by 25 farms, exercise change by 21 farms, foaling by 16 farms, diarrhea by 6 farms, fever by 16 farms, injury by 25 farms, lameness by 25 farms, and respiratory disease by 17 farms.

Fifty-nine horse-level variables were selected in the initial screening for potential inclusion in multivariable analysis (Tables 5-2 to 5-6). Final significant horse variables found by multivariable analysis for first colic are described in table 5-7. The factors that significantly increased the risk of a horse for colic were 1) changes in concentrate feeding during the year compared to no change, 2) age 2-10 years compared to younger and older age group, 3) history of previous colic compared to none, 4) change in the type of hay being fed more than once during the year, 5) feeding higher levels of concentrate, and 6) vaccination for Potomac Horse Fever during the year. Feeding a whole grain with or without other concentrate components decreased the risk of colic relative to not feeding whole grain.

Several concentrate variables showed indications of multicollinearity. Concentrate intake was the variable posing the highest risk ($p=0.0006$), but models with this variable replaced by concentrate feeding frequency ($p=0.004$), or concentrate type ($p=0.016$) were also valid. The analysis would accommodate any one of the three variables individually. However, if two of the concentrate variables were included, the analysis was statistically improved, but no longer differentiated between categories of either variable. The alternate analysis using all colics contained all the same variables except that the type of concentrate was more explanatory than the concentrate intake; feeding sweetfeed or pellet increased risk.

Cribbing had marginal significance ($p = 0.10$), but was not selected in the multivariable analysis for increasing risk of colic.

The role of the random effects variable was negligible on the whole model. The coefficient for the farm variable (%SCL) was very small and the difference between the analysis with and without the random effect was not significant ($p=0.5$). Age was the only pre-identified confounder included in the final analysis, other than farm. Breed, gender, stall-time, and use were not selected as significant. Forcing these confounders into the final analysis made no change in the significant variables selected or the size of the odds ratios, so they were not included.

Discussion

Previous reports which identified colic risk factors have been based on clinical impressions, case reports or case series. Most studies have not used a random population of healthy horses as the control when comparing factors for risk. Two case-control studies have recently examined similar possible risk factors using retrospective exposure information and controls chosen from non-colic patient populations.

Reeves and Salmon[132,133] compared 406 colic cases from 5 universities with 406 non-colic cases as controls using logistic regression to select significant variables. Risk was increased for breeding horses over pleasure horses, Arabs over Thoroughbreds, horses cared for by trainers or managers over horses cared for by owners, horses on diets with a high proportion of corn and horses without water in outside enclosures. Risk was decreased if horses had access to 2 or 3 pastures during each month compared with horses with no pasture access or if horses received a daily worming product (although this group size was very small).

This study did not identify the same risks as Reeves' study. Reeves'[132] study by design had a colic case definition that was more exclusive; a colic case had to be serious enough for the horse to be referred to a university. In the present study, less than 25% of the colic cases were serious enough to require more than one treatment and only 4 had surgery (Chapter 4). The controls in Reeves' study were horses with other types of health problems. The studies both involved predominately Thoroughbreds from the northeastern region of the United States, but Reeves' study included horses from all sizes of horse farms whereas our study was limited to farms with more than 20 horses. Several factors were not examined in a similar manner, so it is difficult to compare results. Variables that addressed numbers of caretakers were not significantly different between high and low level colic incidence density farms in our study. Pasture use was not addressed in terms of the number of different pastures used in our study. The number of housing/pasture changes for the year and low or no stall time were significant on the univariate analysis, but were not selected in the multivariable analysis. Dietary corn was not distinguished from other diet components in our study as most feedstuffs were commercially prepared and contained varying proportions of multiple grain products.

In another recent case-control study, Cohen et al.[131] used data from 821 cases selected by practicing veterinarians in Texas and matched controls that were the next non-colic emergency treated by the same veterinarian. This case definition would select a similar case population in terms of severity of disease as our study because 68% of our colics were seen by a veterinarian (Chapter 4). The breed, use, and farm size of this population would probably be different, and many management and nutritional factors could potentially differ because of the region. Risk factors identified through logistic regression in Cohen's study were history of previous colic, recent change in stabling in the past 2 weeks, recent change in diet, and recent change in level of activity. Variables related to previous colic and frequent dietary changes, either in concentrate or hay, were also selected in our study. Variables related to frequent housing and pasturing changes and frequent changes in exercise were significant in univariate analysis but not in multivariable analysis.

Uhlinger [145], in a practice based study in North Carolina, found an increase in colic incidence associated with increased average age, parasite control measures, number of animals transported per year, and population density. No association was reported for season of year, feeding practices, use and breed. Details of the risk analysis were not reported.

Other reports are limited to comparisons of the age, breed, and sex for colic cases with the proportions for the total hospitalized population at the same center. Except for early studies that showed increased risk for standardbreds[146] and Arabians[22], signalment has not been demonstrated as a colic risk factor. However, some case series do suggest gender or age are associated with risk for specific types of colic. Lipoma associated obstructions[94] were related to older age and colonic volvulus were increased in mares with foals[130]. With the broad definition of colic used in our study, and a very low number of these diagnoses (1 lipoma, 1 colonic torsion) (Chapter 4), these effects would not be distinguishable. Information collected in our study was dependent on owner compliance and whether the information was complete and consistently reported among farms throughout the study period. Owner commitment remained good for the year once the farm initiated the study. Categorical analysis using broad groupings should have minimized the minor variations in reporting. Although owners were given predefined categories on the farm questionnaire some responses still fit multiple categories.

One problem area noted in the analysis was the division of daily time for the horse between stall, pasture, paddock, and work. Stall time seemed the most consistently reported time, therefore, paddock time or pasture time were all considered as non-stall time independent of the enclosure size or presence of forage.

Answers to questions about sequence of feeding and temperament variables were difficult to classify because responses didn't seem uniform.

Another area where error may have been introduced was related to the time the questionnaire was given. Profiles of nutrition, time and exercise categories were assigned based on information obtained at the start of the study. For most horses this was during the winter months of November, December, or January. Change in the information later in the year would be reported on the calendar but not reflected in the categorization of variables used in the analysis.

Events and changes were analyzed by assigning the horse to a frequency category and counting the number of events in each category over the year. A possible source of error in the this frequency estimate could occur from underreporting. Owner reporting on the calendar appeared better for more clearly defined the events. For example, PHF vaccination was a specifically defined event and is expected to have been reported correctly. The PHF vaccination could have occurred following the colic and is therefore descriptive of the preventative health program of the horse for the year.

The exercise variable appears compromised by an underreporting bias. Changes were reported for only 31% of the horses, which appears low. Pasture/stable changes and management changes varied in what owners considered important to report which may result in reporting bias. Nutritional changes also could be influenced by whether the owner reported every small alteration in amount or frequency or just major changes in feed or frequency. The likeliest error is that horses with unreported events are misclassified as having zero events. This misclassification could be non-differential, that is, error for horses without colic is equal to error for horses with colic, or differential, error more likely for horses without colic. It is unlikely that horses with colic had under-reporting compared to horses without colic. Either non-differential or differential misclassification could decrease the IDR, but would have to be large to have a major impact. Overreporting would have a negligible influence, since the total number of events were only used for assignment into broad categorical ranges.

Underreporting could be a source of bias if the farms that reported less events and changes also reported less colic. This bias was not important as the correlation between farm colic incidence density and number of events (all types) reported was $r=0.34$. If underreporting occurred, it would be expected that all multiple event variables would be significant. This was not seen, variables such as number of concentrate changes and hay changes were significant, while other variables such as number of farrier events, number of additive changes and vaccinations other than PHF were not. Number of concentrate changes and hay changes, and PHF vaccination were strongly significant and I think represent true associations with colic risk.

Logistic regression was used in multivariable analysis to measure effect of one variable while controlling all others that are used in the analysis. Possible confounding variables in this study were farm, age, gender, breed, intake of concentrate, pasture/stall time, and use. Farm effects were controlled by the random effects model[156,167]. The random effect term appeared to be negligible in the final analysis with all variables included. Age and concentrate intake were selected in the analysis. Breed, use, stall time, and gender were not selected and even when forced into the analysis, ignoring their statistical value as explanatory variables, did not change the analysis. Stall time is indirectly accounted for by concentrate intake in the analysis, most horses with no concentrate intake are those with no stall time since they are on pasture 24 hours/day.

A meaningful multiple logistic regression analysis for farm variables could not be attained due to the low number of farms (n=31). The significance of these variables may have been undetectable due to lack of power. Alternatively horses on a farm may be different enough that horses are better described individually for most variables. Variables selected at the farm level were tried in the individual factor multiple logistic regression, but none were significant.

The analysis using only the first colic for each horse is statistically preferable to the analysis using all colics as it ensures all first colic cases are independent. However, it means that some of the colic episodes can not be used. In the analysis with all colic cases used, horses experiencing more than one colic had more influence than horses with only one colic. Both analyses selected the same variables in the logistic regression except for the nutritional terms regarding concentrate. In the first colic analysis, the concentrate intake was a stronger variable than the concentrate type variable, whereas in the all colic analysis the concentrate type variable was stronger than intake variable. The reduced risk from feeding specific types of whole grain remains constant between the two analyses.

A history of colic has been previously identified as a risk factor by several studies[7,97,98,127,131]. Age has been identified as a risk factor by Sembrat[146] and Reeves[22]. The well accepted age related types of colic including lipomas in older horses and meconium or ascarid impactions in young horses[31] were so infrequent in this cohort that their effect was outweighed by risk for the young adult. Age can be thought of as a marker for numerous use, exercise and nutritional factors. The 2-10 age group includes the horses that were being managed most intensively.

Numerous nutritional factors have been cited as risks for colic but with minimal epidemiological or experimental basis. The list includes feeding high fiber feedstuffs, pelleted feed, high-concentrate diets, abnormal or spoiled feed. Other risk factors cited are ingestion of certain seeds, bedding, sand, or foreign materials, changes in diet or feeding schedule, decreased water intake, poor dentition, and overeating[179]. Clarke et al.[12] reviewed the negative physiological consequences of a high energy, low forage diet on the fluid balance, motility, and microflora of the equine digestive tract. Our finding that higher concentrate intakes were associated with the highest colic risk support the hypothesis that high concentrate diet changes gastrointestinal activity which may lead to gut dysfunction.

The nutritional risk factors related to use of concentrate, level of concentrate intake, concentrate type, feeding frequency, and changes in feeding were significant in this analysis. Risk was lowest if no concentrate was fed. The number of concentrate changes during the year seemed independent of the other variables describing concentrate. The other variables, the type, amount, and frequency of feeding were interrelated and the effects could not be separately evaluated in this analysis. Type and frequency would be expected to be confounded by intake, possibly horses eating only sweetfeed have increased risk because they also have a higher intake of concentrate compared to horses eating other types of feed. The concentrate intake variable seems the most informative and most consistent. Pellet and sweetfeed increased risk if fed as the only concentrate component. When the question was posed whether pellet or sweetfeed were fed at all, which includes fed alone or fed in combination with each other or with straight grain, no increased risk was demonstrated. This suggests that type, intake and frequency are all important.

No previous association between PHF vaccination and colic has been reported. I think this association represents a marker for health events for the horse and possibly for other management factors for the farm. The farms reporting a history of PHF were marginally significant for increased colic on the farm univariate analysis. Vaccination for PHF was relatively common, 48% of equivalent horse-years, and was comparable to the tetanus vaccination rate, and owners in the study region were highly aware of this disease because of the relation of the farms to the

Potomac River and the history of the original outbreaks. Vaccination for PHF would be expected to be included in the health regimen of any horse with existing health problems, a farm with history of PHF problems or any farm on a high level of preventative medicine. Therefore, PHF vaccination may be an effect rather than a cause of colic. In preliminary logistic regression attempts, variables related to the number of health problems or number of treatments were significant in the analysis. However when vaccination events were evaluated, other health variables were replaced by the variable for vaccination by PHF.

Parasites have always been considered a major cause of colic. Farms in the study reported use of anthelmintics for at least some of the horses on the farm during the year. No attempt was made to judge whether the anthelmintic programs were adequate, but since a large proportion of the horses (88%) received regular anthelmintic administration, I did not expect to see parasites as a risk factor in this study. Some evidence of colic related to parasites was noted in the univariate analyses. Incidence density for horses with no history of parasite control in 1990 was 0.36, and ID for horses with no reported parasite control during the study year was 0.15. The number of horses without preventive anthelmintic was small, so that this effect on the total population colic incidence was overshadowed by other stronger explanatory factors.

In conclusion, previous colic, age, increased concentrate intake and/or concentrate type, changes in feeding and medical treatments increase the risk of colic on farms with 20 or more horses in Loudoun county Virginia and Montgomery County Maryland. Although these results can be generally applied to other similar horse populations, further investigation into the interrelationships of type, amount and frequency of feeding concentrates and clearer definition of time relationships of events with colic is recommended before they are used for specific management decisions on horse farms.

TABLE 5-1 FARM-LEVEL VARIABLES: UNIVARIATE TESTS

Table 5-1 FARM VARIABLES * Selected for farm logistic regression	CATEGORIES (n)	P-Value
Farm		
State	VA(23), MD(8)	0.51
Time horses kept on farm*	> =5 years(26), < 5 years(5)	0.07
Time farm owned by present owner*	> =5 years(28), < 5 years(3)	0.005
Previous use other than horse farm	Yes(23), No(8)	0.80
Current use other than horse farm	Cattle(12), None(19)	0.45
Employees FT=fulltime, PT=parttime		
Low number employees	> 3 FT+PT(20), < =3FT+PT(11)	0.66
High number employees	> 10 FT+PT(6), < 10 FT+PT(25)	0.72
Low number FT employees	FT > 2(18), FT < =2(13)	0.74
More PT than FT employees	PT > FT(8), PT < FT(23)	0.27
No PT employees	PT=0(12), PT > 0(19)	0.55
Horses on farm		
Number resident horses	> =25(17), < 25(14)	0.44
Visitor horses	Yes(7), No(24)	0.41
Boarder horses*	Yes(12), No(19)	0.19
Variation in number during year*	= > 10difference(4), < 10difference(27)	0.04

Table 5-1 FARM VARIABLES * Selected for farm logistic regression	CATEGORIES (n)	P-Value
Feeding		
Concentrate(conc) source	Home only(0), Commercial bag(24), Commercial bulk(1), Combination(6)	0.51
Conc. feedings per day	3x/day(6), 2x/day(17), 1x/day(1), Variable(7)	0.40
Order of feeding	Conc then hay(3), Hay then conc(13), Hay ad lib(4), Together(3), Variable(8)	0.61
Conc. shipment frequency	< = 1x/week(17), > 1x/week, < 1x/month(11), > = 1x/month (3)	0.45
Hay source	Home grown(4), Locally grown(12), Out of state(9), Combination(6)	0.83
Hay feedings per day*	3x/day(6), 2x/day(6), Ad lib(16), Variable(3)	0.07
Hay shipment frequency	< = 1x/week(4), > 1x/week and < = 1/month(6) > 1x/month(16), Variable(2), None(3)	0.64
Hay storage	Stable(19), Haybarn(5), Other or both(7)	0.99
Hay feeding method in stable	Rack(5), Floor(16), Combination(10)	0.86
Hay feeding method in pasture	Rack(4), Ground(18), None(3), Combination(6)	0.72
Hay analysis done	Yes(13), No(18)	0.34
Salt usage	Yes(31), No(0)	
Type of salt	Plain white(4), Trace-mineralized(24), Both(3)	0.58
Salt feedings per day*	Ad lib(29), Variable(2)	0.11
Salt feeding method	Block(28), Block and other(3)	0.18
Supplement usage	Yes(27), No(4)	0.48
Supplement type*	Mineral(1), Vitamin(2), Mineral and vitamin(6), Mineral, vitamin and electrolytes(5), Other Combination(13), None(4)	0.16
Supplement feedings per day	2x/day(5), 1x/day(17), Ad lib(2), Variable(3), None(4)	0.11
Supplement feeding method	Block(1), Mixed with conc(20), Loose(0), Combination(5), None(5)	0.37
Supplements available in pasture	Yes(8), No(23)	0.40
Stable management		
Bedding type	Straw(9), Shavings(5), Sawdust(7), Combination(10)	0.59
Frequency bedding changed *	1x/day(15), > 1x/day and < 1x/week(5), 1x/week(5), Other(6)	0.17
Frequency stalls cleaned	1x/day(21), > 1x/day(7), Variable(3)	0.68
Water source for stable	Well(30), Other(1)	0.69
Water delivery in stable*	Automatic waterer(3), Buckets(28)	0.11
Frequency water checked in stable	> = 3x/day(13), 2x/day(8), 1x/day(6), Variable(4)	0.87
Frequency buckets cleaned in stable	> = 1x/day(18), > 1x/day(13)	0.39

Table 5-1 FARM VARIABLES * Selected for farm logistic regression	CATEGORIES (n)	P-Value
Pasture management		
Water source for pasture Ground=pond, stream, or spring	Well(25), Ground(2), Well and ground(4)	0.60
Water delivery in paddocks/pastures	Automatic waterer(8), Buckets(3), Tub(12), Ground(2), Combination(6)	0.70
Frequency water checked in pasture	>1x/day(4), 1x/day(19), <1x/day(8)	0.92
Predominant forage type in pasture	Grass(11), Mix(19), Weed(1)	0.70
Pastures fertilized*	Yes(13), No(18)	0.20
Pastures clipped	Yes(31), No(0)	
Pastures seeded	Yes(15), No(16)	0.49
Feces removed from pasture	Yes(4), No(27)	0.79
Pastures vacuumed	Yes(0), No(31)	
Pastures rotated	Yes(9), No(22)	0.90
Pastures dragged or harrowed	Yes(20), No(11)	0.51
Predominant soil type*	Clay(18), Black dirt(3), Rocky(2), Unknown(3), Combination(5)	0.07
Farm health history		
Colic in past 5 years	Yes(18), No(13)	0.34
Strangles	Yes(3), No(28)	0.31
Potomac Horse Fever*	Yes(6), No(25)	0.05
Salmonella	Yes(4), No(27)	0.51
Gastric Ulcers	Yes(10), No(21)	0.83
Foal pneumonia	Yes(6), No(25)	0.92
Rhinopneumonitis	Yes(1), No(30)	0.69
Botulism	Yes(0), No(31)	
Other disease*	Yes(11), No(20)	0.22*
Records		
Records kept on farm	Yes(30), No(1)	0.78
Feeding records	Yes(12), No(19)	0.33
Health records	Yes(29), No(2)	0.63
Breeding records	Yes(18), No(13)	0.37
Training records	Yes(14), No(17)	0.73
Frequency of deworming	< 2 months(2), 2 months(19), 3 or 4 months(4), Variable(5)	0.54
Proportion of fecal samples positive for parasite eggs (15 samples per farm, 1 farm not sampled)	<0.2(14), >0.2(16)	0.40
Pasture crude protein rank		
Spring	High(14), Low(13)	0.71
Summer	High(10), Low(13)	0.29
Fall*	High(12), Low(11)	0.11

Table 5-1 FARM VARIABLES * Selected for farm logistic regression	CATEGORIES (n)	P-Value
Pasture digestible energy rank Spring Summer Fall	 High(11), Low(16) High(12), Low(11) High(15), Low(8)	 0.37 0.50 0.31
Hay crude protein rank	High(12), Low(18)	0.80
Hay digestible energy rank	High(9), Low(21)	0.64

TABLE 5-2 HORSE CHARACTERISTICS: UNIVARIATE TESTS

Table 5-2 HORSE VARIABLES * selected for Logistic Regression (LR)		#colic	horse-years	ID	p-value z-test	IDR(95% test-based CI)
Gender	Female	45	438	0.10	0.60	0.9(0.6-1.3)
	Stallion	9	109	0.08	0.36	0.7(0.4-1.5)
	Gelding	50	437	0.11		
*Age	>10 years	18	243	0.07	0.23	1.6(0.7-3.4)
	2-10 years	76	526	0.14	0.0004	3.1(1.7-5.8)
	<2 years	10	215	0.05		
*Breed	Arab	1	31	0.03	0.63	0.6(0.1-4.9)
	Quarterhorse	2	48	0.04	0.76	0.8(0.2-3.8)
	Pony	4	52	0.08	0.57	1.4(0.4-5.1)
	Other	4	49	0.08	0.52	1.5(0.4-5.3)
	Warmblood	9	73	0.12	0.11	2.3(0.8-6.3)
	Thoroughbred	78	620	0.13	0.04	2.3(1.0-5.2)
	Crossbred	6	111	0.05		
*Previous colic in the last 5 years	Yes	25	93	0.27	0.0000	3.0(2.0-4.6)
	No	79	890	0.09		
Time on farm	<=3 years	19	266	0.07	0.04	0.6(0.4-1.0)
	>3 years	85	718	0.12		
*Vices	any type	24	117	0.24	0.0005	2.2(1.4-3.5)
	No	80	866	0.09		
*Cribber	Yes	12	48	0.25	0.002	2.5(1.4-4.5)
	No	92	935	0.10		
*Temperament	Excitable	12	115	0.1	0.58	0.8(0.5-1.6)
	Aggressive	0	14	0	0.18	
	Normal or unspecified	24	302	0.08	0.06	0.6(0.4-1.00)
	Quiet	68	551	0.12		
*Pecking order position	Bottom	22	125	0.18	0.03	1.8(1.0-3.0)
	Top	19	169	0.11	0.67	1.1(0.6-2.0)
	Alone	2	9	0.21	0.33	2.1(0.5-8.6)
	Unknown	24	309	0.08	0.34	0.8(0.5-1.3)
	Middle	37	371	0.10		

TABLE 5-3 MANAGEMENT RELATED TO HOUSING AND PASTURE: UNIVARIATE TESTS

Table 5-3 HOUSING VARIABLES * selected for LR		#colic	horse-years	ID	p- value z-test	IDR(95% test-based CI)
Paddock used	Yes	16	119	0.13	0.31	1.3(0.8-2.2)
	No	88	864	0.10		
*Time in stall per day	23-24 hours	4	51	0.12	0.61	1.3(0.5-3.9)
	17-22 hours	31	213	0.15	0.001	2.5(1.4-4.3)
	9-16 hours	48	357	0.13	0.002	2.3(1.4-3.8)
	1-8 hours	2	41	0.05	0.38	0.8(0.2-3.5)
	None	19	320	0.06		
*Bedding used in stall	Shavings	24	193	0.12	0.01	2.1(1.2-3.8)
	Straw	18	186	0.10	0.12	1.7(0.9-3.1)
	Sawdust	38	19	0.17	0.0001	3.0(1.8-5.0)
	Combination	5	51	0.10	0.29	1.7(0.6-4.5)
	Unknown bedding	0	9	0	0.46	
	Not stalled	19	326	0.06		
Pasture type	Grass	28	261	0.11	0.32	1.6(0.6-4.1)
	Clover	28	270	0.10	0.36	1.6(0.6-4.0)
	Orchardgrass	36	270	0.13	0.14	2.0(0.8-5.0)
	Dirt	4	79	0.05	0.69	0.8(0.2-2.8)
	Weeds	3	29	0.10	0.55	1.5(0.4-6.4)
	No pasture	5	75	0.07		
*Pasture size	< 1	24	148	0.16	0.06	2.4(1.0-6.2)
	acre	37	350	0.11	0.33	1.6(0.6-4.0)
	1-10 acres	31	341	0.09	0.52	1.4(0.5-3.5)
	> 10 acres	7	69	0.10	0.47	1.5(0.5-4.8)
	Size unknown	5	75	0.07		
	No pasture					
*Number of management events reported during year	1-3	36	323	0.11	0.002	2.3(1.3-3.9)
	4-10	32	183	0.18	0.00000	3.6(2.1-6.1)
	>10	16	66	0.24	.0000	5.0(2.8-9.0)
	None	20	411	0.05		
*Number of housing/pasturing changes reported during year	1-3	33	289	0.11	0.04	1.6(1.0-2.6)
	4-10	21	102	0.21	0.0000	2.9(1.8-4.9)
	>10	12	51	0.24	0.0001	3.4(1.8-6.2)
	None	38	542	0.07		

TABLE 5-4 MANAGEMENT RELATED TO USE: UNIVARIATE TESTS

Table 5-4 USE VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Use	Lessons	1	63	0.02	0.26	0.2(0.03-1.7)
	Foal, Weanling, Yearling	5	156	0.03	0.24	0.5(0.1-1.6)
	Hunt	5	75	0.07	1.00	1.0(0.3-3.4)
	Pleasure	12	116	0.10	0.40	1.6(0.6-4.4)
	Breeding	20	170	0.12	0.25	1.8(0.7-4.6)
	Dressage	11	79	0.14	0.16	2.1(0.7-5.9)
	Show	12	84	0.14	0.14	2.1(0.8-6.0)
	Race	12	78	0.15	0.11	2.3(0.8-6.4)
	Training	8	34	0.24	0.02	3.5(1.2-10.1)
	Event	13	54	0.24	0.009	3.6(1.4-9.5)
	No use	5	75	0.07		
Breeding events recorded	Yes	6	54	0.11	0.92	1.0(0.5-2.4)
	No	98	929	0.11		
Weaning reported	Yes	10	147	0.07	0.12	0.6(0.3-1.2)
	No	94	836	0.11		
History of foaling(adult mares)	Yes	9	69	0.13	1.0	1.0(0.5-2.2)
	No	33	259	0.13		
Foaling in study year(adult mares)	Yes	14	88	0.16	0.34	1.4(0.7-2.6)
	No	28	239	0.12		
Time at work	> 1 hour per week	33	273	0.12	0.17	1.4(0.9-2.1)
	> 1 hour per day	24	181	0.13	0.11	1.5(0.9-2.4)
	None	47	530	0.09		
*Exercise changes reported	Yes	37	208	0.18	0.0003	2.1(1.4-3.1)
	No	67	776	0.09		
*Number transports during year	1-6	55	418	0.13	0.02	1.6(1.1-2.3)
	>6	7	61	0.11	0.44	1.4(0.6-3.0)
	None	42	504	0.08		
Horse left and returned during the year (multiple start dates)	Yes	10	89	0.11	0.85	1.1(0.6-2.0)
	No	94	894	0.11		
Horse entered study after start	Yes	16	216	0.07	0.11	0.6(0.4-1.1)
	No	88	769	0.11		
History of Farrier in last 6 months	Yes	28	322	0.09	0.21	0.8(0.5-1.2)
	No	76	662	0.11		

Table 5-4 USE VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
Number farrier visits during year	1-3	24	322	0.07	0.13	0.6(0.3-1.1)
	4-6	30	262	0.11	0.91	1.0(0.5-1.7)
	>6	31	286	0.11	0.76	0.9(0.5-1.6)
	None	19	161	0.12		

TABLE 5-5 MANAGEMENT RELATED TO NUTRITION: UNIVARIATE TESTS

Table 5-5 NUTRITION VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Diet	Concentrate and pasture	4	17	0.24	0.009	5.2(1.5-18.0)
	Conc, pasture and hay	84	641	0.13	0.03	2.9(1.1-7.4)
	Conc and hay	7	77	0.09	0.27	2.0(0.6-6.6)
	Growing (Foal, weanling, Yearling)	5	162	0.03	0.55	0.7(0.2-2.5)
	Forage only	4	87	0.05		
*Conc dry matter	< 2.5 kg/day	17	257	0.07	0.20	2.0(0.7-5.9)
	2.5-5.0 kg/day	37	304	0.12	0.007	3.7(1.4-9.7)
	> 5.0 kg/day	46	298	0.15	0.0009	4.7(1.9-11.9)
	0 kg/day	4	124	0.03		
*Conc crude protein	0.35 kg/day	26	322	0.08	0.08	2.5(0.9-6.9)
	0.35-0.75 kg/day	32	254	0.13	0.006	3.9(1.5-10.2)
	>0.75 kg/day	42	283	0.15	0.001	4.6(1.8-11.7)
	0 kg/day	4	124	0.03		
*Conc digestible energy	10 Mcal/day	28	350	0.08	0.08	2.5(0.9-6.8)
	10-20 Mcal/day	32	251	0.13	0.005	4.0(1.5-10.3)
	>20 Mcal/day	40	259	0.15	0.001	4.8(1.9-12.1)
	0 Mcal/day	4	124	0.03		
*Conc type	Only Pellet	19	170	0.11	0.02	3.3(1.2-9.0)
	Only Sweetfeed	55	363	0.15	0.002	4.4(1.7-11.1)
	Combination or prepared mix	23	302	0.08	0.13	2.2(0.8-6.2)
	Only Grain	3	33	0.09	0.19	2.6(0.6-11.1)
	None	4	116	0.03		
*Conc feedings frequency	1/day	1	60	0.02	0.51	0.5(0.05-4.1)
	2/day	64	627	0.10	0.03	2.9(1.1-7.7)
	> 2/day	35	182	0.19	0.0003	5.6(2.2-13.9)
	0/day	4	115	0.03		
*More than one type of conc	Yes	22	283	0.08	0.09	0.7(0.4-1.1)
	No	82	700	0.12		
Type conc part of diet	Pellet	31	295	0.11	0.97	1.0(0.6-1.5)
	No	73	689	0.11		
	Sweetfeed	72	627	0.11	0.25	1.3(0.8-1.9)
	No	32	356	0.09		
	Prepared Mixture	12	170	0.07	0.12	0.6(0.3-1.1)
	No	92	814	0.11		
	*Grain	14	210	0.07	0.05	0.6(0.3-1.00)
	No	90	773	0.11		

Table 5-5 NUTRITION VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Sequence of feeding	Water first	7	54	0.13	0.17	1.9(0.8-4.6)
	Conc first	9	109	0.08	0.69	1.2(0.5-2.7)
	Hay first	45	414	0.11	0.14	1.6(0.9-2.8)
	None or only 1 component	8	133	0.06	0.75	0.9(0.4-2.1)
	Variable	21	72	0.29	0.0000	4.2(2.3-7.9)
	Hay and concentrate together	14	202	0.07		
*Hay feeding method	Measured	73	492	0.15	0.0002	2.3(1.5-3.5)
	No hay	4	76	0.05	0.69	0.8(0.3-2.3)
	Free choice	27	416	0.06		
*Hay type	Timothy	66	615	0.11	0.16	2.0(0.7-5.4)
	Alfalfa	13	171	0.08	0.53	1.4(0.5-4.3)
	Orchardgrass	16	79	0.20	0.01	3.8(1.4-10.5)
	Grass Mix	5	44	0.11	0.25	2.1(0.6-7.7)
	No Hay	4	75	0.05		
*Hay feeding frequency	1/day	35	220	0.16	0.03	3.0(1.1-8.0)
	2/day	11	119	0.09	0.34	1.7(0.6-5.3)
	>2/day	31	231	0.13	0.07	2.5(0.9-6.9)
	Always available	23	338	0.07	0.65	1.3(0.4-3.7)
	Not fed:	4	75	0.05		
	Pasture only	0	58	0		
	Conc and pasture	4	17	0.23		
*Supplements(Vitamin-Mineral	Yes	49	335	0.15	0.005	1.7(1.2-2.5)
or other Commercial additive)	No	55	649	0.08		
Additives (non-commercial feedstuffs fed						
by owner in addition to conc)	Yes	14	101	0.14	0.28	1.4(0.8-2.4)
	No	90	883	0.10		
*Number of dietary supplements and						
additives in addition to conc and hay	1	28	250	0.11	0.17	1.4(0.9-2.2)
	2	25	150	0.17	0.003	2.1(1.3-3.3)
	>2	7	36	0.19	0.03	2.4(1.1-5.2)
	0	44	547	0.08		
Treats fed regularly	Yes	47	378	0.12	0.16	1.3(0.9-1.9)
	No	57	605	0.09		
*Bran usage	Daily	5	19	0.26	0.02	2.7(1.1-6.5)
	Weekly or infrequently	11	52	0.21	0.01	2.2(1.2-4.1)
	None	88	913	0.10		

Table 5-5 NUTRITION VARIABLES * selected for LR		#colic	horse-years	ID	p value z-test	IDR(95% test-based CI)
*Number nutritional changes during the year(not treats or bran)	1	15	136	0.11	0.06	1.8(1.0-3.2)
	2	13	127	0.10	0.12	1.6(0.9-3.1)
	>2	42	177	0.24	0.0000	3.8(2.5-5.8)
	0	34	543	0.06		
Changes reported	*Bran: Yes	36	150	0.24	0.0000	3.0(2.0-4.3)
	No	68	834	0.08		
	*Hay: 1	13	149	0.09	0.91	1.0(0.6-1.9)
	>1	32	137	0.23	0.0000	2.8(1.8-4.2)
	No	59	698	0.08		
	*Conc: 1	26	125	0.21	0.0000	2.9(1.8-4.5)
	>1	24	114	0.21	0.0000	2.9(1.8-4.6)
	No	54	745	0.07		
	*Additive: Yes	20	126	0.16	0.05	1.6(1.0-2.6)
	No	84	858	0.10		

TABLE 5-6 MANAGEMENT RELATED TO HEALTH: UNIVARIATE TESTS

Table 5-6 HEALTH VARIABLES * selected for LR	#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
(1991 foals excluded from history variables)					
History of health problem (1990 or later)					
*Illness	23	79	0.29	0.0000	3.1(2.0-4.8)
No	79	834	0.09		
*Injury	25	106	0.24	0.0001	2.5(1.6-3.8)
No	77	807	0.10		
*Treatment or antibiotic given	25	122	0.20	0.001	2.1(1.4-3.3)
No	77	791	0.10		
*History of deworming in 1990 Yes	94	891	0.11	0.0005	0.3(0.2-0.6)
No	8	23	0.36		
History in last 5 years Surgery	7	40	0.17	0.22	1.6(0.8-3.4)
No	95	873	0.11		
*Colic	25	70	0.36	0.0000	3.9(2.6-6.0)
No	77	844	0.09		
History of Vaccination in 1990					
1 or more of any type	88	762	0.11	0.44	1.2(0.9-2.2)
No	14	151	0.09		
Tetanus	82	701	0.12	0.38	1.2(0.8-2.0)
No	20	213	0.09		
*Encephalomyelitis(combination)	73	526	0.14	0.004	1.9(1.2-2.8)
No	29	387	0.07		
*Rhinopneumonitis	80	615	0.13	0.02	1.8(1.1-2.8)
No	22	298	0.07		
Influenza	84	705	0.12	0.21	1.4(0.8-2.3)
No	18	209	0.09		
*Rabies	66	470	0.14	0.007	1.7(1.2-2.6)
No	36	444	0.08		
Strangles	22	147	0.15	0.14	1.4(0.9-2.3)
No	88	766	0.10		
*Monocytic ehrlichiosis(PHF)	41	281	0.15	0.04	1.5(1.0-2.2)
No	61	632	0.10		
History of health problem in the month before started study Any problem (recent vet visit, illness, phenylbutazone, surgery, antibiotic, treatment, or injury	32	253	0.13	0.24	1.3(0.8-1.9)
No	72	731	0.10		
*Use of phenylbutazone	12	56	0.21	0.1	2.1(1.2-3.8)
No	92	921	0.10		
*Other treatment or antibiotic	12	63	0.19	0.03	1.9(1.1-3.5)
No	92	921	0.10		

Table 5-6 HEALTH VARIABLES * selected for LR		#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
Drug received daily on profile	Yes	3	23	0.13	0.74	1.2(0.4-3.8)
	No	101	960	0.11		
*Number health events during year	1-5	35	261	0.13	0.13	1.7(1.1-2.7)
	>5	22	117	0.19	0.0004	2.4(1.5-4.0)
	0	47	605	0.08		
*Number veterinarian visits during year						
	1-5	53	504	0.11	0.45	1.2(0.8-1.8)
	>5	19	120	0.16	0.04	1.8(1.0-3.1)
	0	32	360	0.09		
Health events by type						
*Number drug treatments:	1-5	33	254	0.13	0.03	1.6(1.0-2.5)
	>5	22	110	0.20	0.0002	2.5(1.6-4.1)
	0	48	620	0.08		
*Number therapy treatments:	>0	21	118	0.18	0.01	1.9(1.2-3.0)
	0	83	866	0.10		
Number routine health events:	>0	59	486	0.12	0.13	1.3(0.9-2.0)
	0	45	498	0.09		
*Number diagnostic health events:	1-5	40	298	0.13	0.04	1.5(1.0-2.3)
	>5	6	33	0.18	0.09	2.0(0.9-4.7)
	0	58	653	0.09		
Number surgical health events:	>0	6	63	0.10	0.79	0.9(0.4-2.0)
	0	98	920	0.11		

Table 5-6 HEALTH VARIABLES * selected for LR	#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
Health events by body system					
Reproductive	21	166	0.13	0.36	1.3(0.8-2.0)
No	83	818	0.10		
Gastrointestinal (other than colic)	4	22	0.18	0.27	1.7(0.6-4.7)
No	100	961	0.10		
Skin	14	97	0.14	0.21	1.4(0.8-2.5)
No	90	887	0.10		
Respiratory	6	68	0.09	0.64	0.8(0.4-1.9)
No	98	915	0.11		
*Musculoskeletal, nervous, hoof	34	209	0.16	0.004	1.8(1.2-2.7)
No	70	775	0.09		
Dental	24	233	0.10	0.89	1.0(0.6-1.5)
No	80	752	0.11		
*Non-specified, treated with anti-inflammatory drugs	20	99	0.20	0.002	2.1(1.3-3.4)
No	84	885	0.09		
Routine health care	47	391	0.12	0.26	1.3(0.9-1.8)
No	57	593	0.09		
*Eye	5	22	0.22	0.08	2.2(0.9-5.2)
No	99	961	0.10		
Other	8	44	0.18	0.12	1.8(0.9-3.6)
No	96	939	0.10		
*Unknown (not classifiable in above categories)	8	44	0.18	0.12	1.6(1.00-2.4)
No	96	939	0.10		
Specific events reported by owner					
*Injury	18	102	0.18	0.02	1.8(1.1-3.0)
No	86	882	0.10		
Fever	5	34	0.15	0.43	1.4(0.6-3.5)
No	99	950	0.10		
Respiratory disease	4	53	0.08	0.48	0.7(0.3-1.9)
No	100	930	0.11		
Lameness	10	77	0.13	0.51	1.2(0.6-2.4)
No	94	906	0.10		
*Number health problems reported 1-2	11	174	0.06	0.39	0.7(0.4-1.5)
3-5	30	296	0.10	0.55	1.2(0.7-2.0)
>5	38	219	0.17	0.006	2.0(1.2-3.3)
0	25	295	0.08		
*Number different health problems reported 1-2	14	214	0.07	0.40	0.8(0.4-1.5)
3-5	54	419	0.13	0.10	1.5(0.9-2.4)
>5	11	55	0.20	0.02	2.3(1.2-4.6)
0	25	295	0.08		

Table 5-6 HEALTH VARIABLES * selected for LR		#colic	horse-years	ID	p value z test	IDR(95% test-based CI)
Number anthelmintic treatments reported	1-3	49	559	0.09	0.14	0.6(0.3-1.2)
	4-6	41	316	0.13	0.74	0.9(0.4-1.8)
	>6	4	40	0.10	0.51	0.7(0.2-2.1)
	0	10	69	0.15		
*Anthelmintic used						
	Ivermectin and other	59	368	0.16	0.0002	2.3(1.5-3.6)
	Other only	3	64	0.05	0.51	0.7(0.2-2.2)
	Unknown	4	82	0.05	0.49	0.7(0.2-2.0)
	None	10	69	0.15	0.04	2.1(1.0-4.2)
	Ivermectin only	28	401	0.07		
Vaccination reported						
	*Any type, (1 or more)	91	788	0.12	0.06	1.7(1.0-3.1)
	No	13	196	0.07		
	Tetanus	53	480	0.11	0.66	1.1(0.7-1.6)
	No	51	503	0.10		
	Encephalomyelitis	53	391	0.14	0.02	1.6(1.1-2.3)
	No	51	592	0.09		
	Influenza	67	633	0.11	0.99	1.0(0.7-1.5)
	No	37	350	0.11		
	*Monocytic ehrlichiosis (PHF)	68	471	0.14	0.0004	2.1(1.4-3.0)
	No	36	512	0.07		
	Rabies	35	278	0.13	0.23	1.3(0.9-1.9)
	No	69	705	0.10		
	Rhinopneumonitis	71	611	0.12	0.20	1.3(0.9-2.0)
	No	33	372	0.09		
	Strangles	16	120	0.11	0.31	1.3(0.8-2.2)
	No	88	864	0.10		
	Botulism or Rotavirus	5	54	0.09	0.77	0.9(0.4-2.1)
	No	99	930	0.11		

TABLE 5-7 VARIABLES SELECTED BY LOGISTIC REGRESSION USING FIRST COLIC FOR EACH CASE.

Variable	Beta-coefficient	Std Error	p-value	Odds Ratio	95%CI
%GM	-5.68	0.77	<0.00	0.3E-02	0.8E-03-0.2E-01
Conc=None				1.0	
Conc Intake= <2.5 kg/day	0.87	0.67	0.20	2.4	0.6-8.8
Conc Intake=2.5-5 kg/day	1.56	0.64	0.01	4.8	1.4-16.6
Conc Intake= >5 kg/day	1.85	0.64	0.004	6.3	1.8-22.0
No Whole Grain Fed				1.0	
Whole Grain Fed	-0.94	0.37	0.01	0.4	0.2-0.8
Conc events =0/study				1.0	
Conc events =1/study	1.07	0.32	<0.001	3.6	1.6-5.4
Conc events>1/study	0.77	0.32	0.02	2.2	1.2-4.1
No History of colic				1.0	
History of colic in last 5 years	1.29	0.32	<0.001	3.6	1.9-6.8
No History of colic -1991 Foal	0.32	0.85	0.70	1.4	0.3-7.3
Hay events=0/study				1.0	
Hay events=1/study	-0.68E-01	0.36	0.85	0.9	0.5-1.9
Hay events>1/study	0.75	0.30	0.01	2.1	1.2-3.8
Age < 2 years				1.0	
Age 2-10 years	1.03	0.43	0.02	2.8	1.2-6.5
Age >10 years	0.47	0.49	0.34	1.6	0.6-4.2
No PHF vaccine				1.0	
PHF vaccine during study	0.71	0.25	0.005	2.0	1.2-3.6
%SCL	0.32	0.17			

Chapter 6

Assessment of Risk Associated with Events in a Prospective Study of Equine Colic

Abstract

A one-year prospective study was conducted on horse farms to examine the risk factors for colic associated with farm, horse, nutrition, health and management factors, events and weather. In the original analysis, events were analyzed based on frequency of events during the study year. This chapter reports results of a nested date analysis to examine colic risk for the time period following an event or weather condition. Farms with greater than 20 horses and owners willing to participate were enrolled from randomly selected horse owners from two adjacent counties of Virginia and Maryland, USA. Baseline information was collected on farm and horse characteristics and management for 31 farms and 1427 horses. Owners kept calendars to record the occurrence of specified events and changes from baseline diet, housing and exercise. Colic was reported by the owner when a horse was observed exhibiting a behavior indicative of abdominal pain. Farms were visited within 48 hours of a colic and every three months to collect information. Meteorological data collected at Dulles International Airport, Virginia, were retrieved from the National Climatic Center, Asheville, North Carolina for the study period.

Horses with colic were assigned the first colic-date and non-cases were assigned a date chosen at random from the time under observation. The odds ratio was determined for the proportion of cases with an event within 14 days prior to the colic-date relative to the proportion of non-cases with an event within 14 days of the random-date. Odds ratios for the 15 to 28 days and 29-42 days before the colic were compared to assess specificity. Weather events were analyzed for the three days before the colic-date or random-date. Three time periods were analyzed in relation to foaling: before, 0-60 days and 60 to 150 days post-foaling. Univariate odds ratios were computed and events were tested in a stepwise multivariable logistic regression for significance.

Significant events were recent vaccination, Odds Ratio (OR)=3.31 (95% Confidence Interval=1.9-6.0); recent transport, OR=3.3 (1.2-5.5); the time period 60 to 150 days post-foaling, OR=5.9 (1.8-13); and recent fever, OR=20 (2.5-169). Snow on the day of the colic, OR=2.8 (1.0-7) and low humidity (<50%) the day before the colic, OR=1.6 (1.0-2.9) were marginally significant weather variables. The vaccination risk in the date analysis was not related to a single vaccine type.

Non-event variables selected in the original cohort analysis were added to the logistic regression analysis to control confounding. Concentrate dry matter intake level; 2.5-5 kg/day, OR=5.0 (1.4-17), >5 kg/day OR=5.8 (1.7-20), and history of previous colic, OR=4.1 (2.1-7.9), remained significant for increased colic risk. The age variable was no longer significant. Whole grain in the diet decreased risk, OR=0.4 (0.2-0.8). Two additional risk factors that were marginally significant (p=0.05-0.1) in the cohort analysis could be added to the analysis: vices and history of encephalomyelitis vaccine. Two interactions were significant: whole grain and transport and whole grain and vices. Snow was no longer significant in the combined analysis. The risk for history of encephalomyelitis vaccination in the combined analysis was thought to be representative of management factors for the farm, rather than related to the vaccine.

The date analysis improved definition of risk for events over the cohort analysis. Risk specific to 14 days after an event was demonstrated for vaccination, transport, and fever. Median time between event and colic was seven days. Risk for the post-foaling mare as proposed by several authors was demonstrated. Weak association of two weather variables was indicated.

Introduction

Events and changes in management, exercise or nutrition are frequently mentioned in the literature as causes of equine colic. Associations of colic with weather[128], dietary changes[90,129], inconsistent management[32], changes in exercise, either strenuous exercise[32] or lack of exercise[31], pregnancy or recent foaling[20] or stressful events[31] such as water deprivation[129] or recent injury or disease[31,32] were suggested in early papers and the same factors have been repeatedly cited over the last 25 years. The original references are based upon opinion, or anecdotal report without appropriate controls or experimental documentation. Descriptions of events are not helpful in managing horses to avoid risk, because they are too general.

Case-control studies have compared the proportion of colic cases with history of a recent event to the proportion of non-colic controls with history of the event. Management factors were examined by Cohen[131] in a case-control study with the colic cases identified prospectively by Texas veterinarians and the next non-colic emergency treated by the same veterinarian used as the control. Participating veterinarians collected information on changes in housing, stabling, diet, or horse activity level, recent deworming, vaccination or transport, plus other descriptive variables relating to history, nutrition, management and horse factors. Event variables significant in logistic regression were recent change in diet, history of previous colic and history of previous surgery. Change in stabling conditions and recent change in horse activity level were significant as individual variables but not in multivariable analysis.

In another case-control study, Reeves[132,133] used cases and controls from five veterinary hospitals in the northeastern United States and Canada. Information was collected on housing, stable and farm environment, pasturing, diet, exercise, and history of breeding, travel, or health problems. No event related risk factor was reported as significant. Logistic regression analysis showed significantly increased odds ratios for the following factors: use for breeding, Arabian breed, care by a trainer or manager, high proportion of corn in the diet and absence of water in outside enclosures. Horses on two or three pastures within the last month had lower risk than horses with no access to pasture.

The association of weather and other recent events to the occurrence of colic in the horse have been examined retrospectively for case series reports in an attempt to confirm the significance of the events as risk factors. Severe weather, weather changes and seasonal weather factors have been linked with colic. Rollins and Clement[15] showed higher incidence of colic in an Arizona practice during hot months of the year and suggested heat stress as a possible cause. Foreman and White[135] reported no correlation between colic incidence and temperature, change in temperature, barometric pressure and change in barometric pressure in a cross-sectional study of colic cases in the University of Georgia ambulatory practice. Moore[136] found no consistent association with weather patterns in a study of thoroughbred mares in Kentucky. Proudman[24] found no correlation between colic incidence and mean monthly temperature, change in monthly temperature, monthly rainfall, and monthly rainfall weighted for temperature in a prospective study in England. Seasonal trends are frequently mentioned[137] and authors have speculated that trends reflect availability and nutrient content of forage. Meagher[126] noted small colon impactions occurred in the fall and early winter. Specht[58] reported sand colic was more frequent from July through December. Wilson[138] noted ulcers were more common during hot weather months. Livesey[91] reported incarceration of the large colon by the suspensory ligament of the spleen was most frequent in the winter. Todhunter[139] did not demonstrate a seasonal difference for gastric rupture.

Reproductive events have been associated with colic. Acquired inguinal hernia for the stallion has been associated with breeding[85], strangulating obstruction observed frequently in the post-partum mare[130,140], and cecal perforation[141,180] has been related to foaling. No causal effect has been discovered though torsion or volvulus is suspected to be related to the return to lush grass pasture for the mare with a foal at her side[117,142].

Other stresses[119], events, and changes are postulated to induce changes in motility, microbial content and water flux in the gastrointestinal tract[12]. Bell and Lowe[16] estimated the probability of severe colic and other injuries at horse shows. Horses had the greatest risk of soft tissue injury, and then other types of injury. The most deaths were associated with colic. Disease probability estimates are not available for horses not at a show to use for comparison. Morris[23] found no relationship between colic and feed changes within 30 days of colic and the horse's previous activity for different types of colic. Dabareiner[143] reported in a case series of large colon impactions that 54% of cases had changes in routine in the two week period prior to the colic, the most frequent routine change being exercise restriction and phenylbutazone treatment for an injury. Reeves[144] reported diet change, foaling, deworming, weather change, change in exercise, recent treatment, shipping or illness for colic cases, but used the information to compare cases that survived to those that died. Uhlinger[145] reported herds with high numbers of animals transported during the year had higher frequency of colic.

In this study a cohort of 1427 horses was followed prospectively, owners recorded events and colic episodes as they occurred in the horses. Colic incidence and colic risk factors for this cohort have been reported in Chapters 4 and 5. In the previous analysis, event data were analyzed by the frequency of the event during the study year. Logistic regression analysis indicated multiple changes in concentrate or hay feeding significantly increased the risk of colic. Other significant horse factors were age, history of previous colic, amount of concentrate intake, and type of health program that includes monocytic ehrlichiosis (Potomac Horse Fever, PHF) vaccination. In this study, analysis was based on whether an event was significantly more likely to have occurred in the time period before the colic than in a time period unrelated to a colic. The risk for colic was hypothesized to increase for several days following certain events or major changes in the horse's nutrition or management or following weather changes.

Materials and Methods

Data collection and categorization-----Cases of colic in a dynamic cohort of 1427 horses on 31 farms were reported for one year. Study design, farm selection and case definition are described in Chapter 4. At the beginning of the study the owners or farm managers were given a horse list, a list of events of interest and monthly calendars. Time on the farm for every horse was recorded on a horse-list. Owners were instructed to record on the calendar any event occurring for any horse. Specific events to be reported are listed in Table 6-1. Colics were to be reported by telephone to the investigators and farms were visited within 48 hours to obtain details concerning the colic case. All farms were visited by the investigators to review calendars and update horse records every three months regardless of the number of colic episodes.

Calendar information was entered by investigators on Lotus 123 (Lotus Development Corporation, Cambridge, MA) spreadsheets by horse identification, major event type, date, and descriptive notes concerning amount or subtype of event. Spreadsheets were imported to dbaseIV (Borland International, Scotts Valley, CA) for sorting, sums, counts and categorical grouping.

Further classification of some event categories was performed by the investigators. Nutrition events were subclassified as changes involving concentrate, hay, bran or additive. Events referring to feeding treats such as apples, carrots or sugar cubes were excluded from analysis because they were too numerous and inconsistently recorded between farms.

Calendar health entries were further classified by type and body system. All treatments and veterinary visits on the day of a colic were excluded because they may have occurred as a result of the colic. Treatments and veterinary visits were categorized as 1) drug, 2) therapy (such as massage, hose, or wrap), 3) routine care (such as Coggins test, dental procedure, prepurchase examination, or reproductive palpation), 4) diagnostic (such as examination, laboratory tests or radiographs for a specific problem) or 5) surgery (such as castration or suturing). Health events were classified by the body system involved as described in Table 6-2. Treatments of phenylbutazone or steroids without a stated reason for treatment were classified as non-specific inflammation. Other events without a specified reason were classified as unknown.

Management events were further classified as a 1) stable, pasture or paddock change, 2) routine horse care such as clipping, weighing, pulling mane, or bathing, 3) farm maintenance such as using flyspray, applying lime to fields, or changing bedding, 4) breeding-related event such as prolonging light exposure, or 5) problem, non-routine, or unusual event as a show, snowstorm, or broken gate.

Horses were classified by dates they received one or more vaccinations during the study and by date they were vaccinated against a specific agent (tetanus, encephalomyelitis, rabies, rhinopneumonitis, influenza, monocytic ehrlichiosis (PHF), strangles, or other).

Local meteorologic data collected at the Dulles International Airport located in Loudoun county, were retrieved from the National Climatic Center in Asheville, North Carolina for the 1991 calendar year. Barometric pressure, high and low temperatures, precipitation (snow or rain) and humidity at 10 AM were recorded for each day of the study. Days were classified for weather events as described in Table 6-4.

Analysis-----Horses with colic were assigned the date of their first colic episode. Horses without colic during the study were assigned a random date within the time they were on the study. A number between 14 and the total number of days a horse was on the study was selected using a computer random number generator function. This number was added to the first start date to yield the random-date used for the control horse. Dates were adjusted for horses leaving and returning during the study to assure the horse was under observation for events for 14 days prior to the assigned random-date. Horses on the study less than 14 days were assigned their last day of observation.

To classify events, all events for each event type for each horse were compared to that horse's assigned random-date or colic-date. If an event occurred less than 15 days before a colic-date or random-date, it was classified as an exposure. The random-date or colic-date itself was excluded since events on that day may have happened in response to the colic. Some horses had multiple events occurring within the two weeks, so each horse was classified as exposed if it had at least one exposure event of the type being evaluated. In addition to colic being evaluated within 14 days of foaling, foaling variables for colic for within 60 to 150 days after foaling or colic 0 to 90 days before foaling were analyzed. A variable was developed for colic within 14 days of a horse starting the study or returning to the study after being off the farm. Significant events within 14 days, (vaccination, fever, and transport) were also examined for the times 15 to 28 days and 29 to 42 days after the event. Weather was analyzed similarly to horse events for time periods: the day of, one day before and two days before the colic-date or random-date. Barometric pressure was also analyzed for a decrease over two days, or four days or an increase over three days.

The odds ratios comparing recent event exposure to no event exposure for each event were computed from the proportion of cases with an event within 14 days prior to the colic-date divided by the proportion of non-cases with an event within 14 days of the random-date. Logistic regression with farm as a random effect was used to select significant ($p<=0.05$) event factors with control for other events and for previously identified risk factors for this cohort (Egret, SERC, Seattle, WA). Events were tested in a forward stepwise-logistic regression to select significant events. Then non-event related variables from the logistic regression analysis of the cohort analysis (age, history of colic, level of concentrate dry matter in daily diet, and whether a whole grain was included in the diet) were added to the event factors in a forward-backward selection step in a combined analysis. Variables from the previous analysis relating to event frequency (number of concentrate changes, number of hay changes and PHF vaccination during the study year) were excluded since they were replaced by new event variables. Finally, all variables originally significant as individual variables in univariate testing that were used to develop the cohort logistic regression analysis were retested to see if any added significantly to the combined analysis. The significance of the random effects term was tested by comparing the analysis with or without the random effects term, the difference in the deviance is used to obtain a p-value. Goodness of fit of the analysis was confirmed by a Hosmer-Lemeshow test (Statistix, Analytical Systems, Tallahassee, FL). Interactions were tested by logistic regression, using the variables in pairs with an interaction term (variable 1, variable 2, and variable 1 X variable 2). Interaction terms with a p-value $<=0.05$ were then tested in the analysis with all main effect terms previously selected. If the analysis was significantly improved by the addition, all variables or interactions were maintained with p-value$<=0.05$.

Results

The number of events, number of horses and farms, and the median number of events per horse are listed in Table 6-1. Examination of the time between events indicated no structure or periodicity. Time from the start of the study, interval between events and frequencies all varied for each horse and between farms. Often events were clustered, such as if there was a health problem and the veterinarian made several visits over several days. One notable characteristic of events was that similar events were clustered on one day for many horses on a single farm, such as 40 horses receiving anthelmintic on a farm on one day.

The univariate odds ratios with confidence intervals are shown in Table 6-2. Events significant by Fishers exact test or Chi square were transport, vaccination, fever, foaling 60-150 days, bran feeding, diarrhea, farm maintenance, health event (any type), and drug. The event variables selected in the logistic regression were recent vaccination, transport, fever, and time period 60 to 150 days after foaling (Table 6-6). The diarrhea variable was unusable in the logistic regression because no controls had diarrhea within 14 days of the random-date. When the cohort risk factors were added to the analysis to control for other risk factors, age was no longer significant. Additional cohort factors that were added to the analysis were history of encephalomyelitis vaccination in the year prior to the study and vices. The final combined analysis is shown in Table 6-7. The Hosmer-Lemeshow test indicated a good fit between the logistic regression analysis and the data ($p=0.78$). The farm random effect in the final analysis was not significant, ($p=0.5$) for the difference between analysis with and without the random effect term.

Two significant interactions were between grain and vices ($p=0.04$) and between grain and transport ($p=0.005$), the horse with grain in its diet and recent transport or vices had increased risk while the horse with grain in its diet and no recent transport or vice had low risk. Interaction terms remained significant when introduced into the analysis with other variables. Only a small number of horses were affected by these interactions, 40 horses were transported and fed grain, and 11 horses had vices and were fed grain.

Eighteen (21%) of the 86 colics were considered serious, defined as requiring multiple treatments, requiring surgery, or resulting in death. With the exception of fever and diarrhea, no identified event was more likely to be associated with serious colic episodes, five of 22 (23%) of the colic cases following vaccination were serious, three of 12 (25%) following transport, and 1 of 6 (17%) related to foaling. Two horses with colic following fever and diarrhea were euthanized, 1 horse with fever alone had mild colic.

Further examination of the vaccination events associated with colic is shown in Table 6-8. Of the 22 horses with vaccinations within 14 days of colic, 14 (64%) received multiple agents and 8 (36%) a single agent (1 strangles, 1 tetanus, 2 rhinopneumonitis and 4 PHF). Three horses received rabies vaccine, 3 strangles, 8 tetanus, 9 encephalomyelitis combinations, 10 rhinopneumonitis, 10 PHF, and 12 influenza vaccine. Compared to the 153 control horses with vaccinations within 14 days of their random-date, 85 (55%) received multiple agents and 68 (44%) a single agent. Differences in proportion of horses receiving multiple vaccines (OR=1.4 (95% CI=0.5-3.9) (p=0.47) or a trend analysis (p=0.37) for the number of vaccines were not significant between cases and controls with events. When risk is examined by type of vaccine all vaccination types had increased odds ratios with the exception of rabies vaccine and the other vaccine group (botulism or rotavirus) (Table 6-2).

Events and colic were not closely linked in time, the number of colics that occurred in the first week was the same as the number in the second week after exposure. Risk levels were not increased for intervals longer than two weeks from the colic. Median time between vaccination and colic for the 22 cases was 6.5 days (range 1-14 days). Odds ratios for the two time periods beyond 14 days were not significantly elevated, 15-28 days: OR=0.9 (95% CI=0.4-1.8), 29-42 days: OR=1.6 (95% CI=0.9-2.9). Median day from transport to colic was 7.5 days (range 1-14 days). The risk was not increased for the times after 14 days, 15-28 days: OR=1.0 (95% CI=0.4-2.1), 29-42 days: OR=1.1 (95% CI=0.5-2.6). Median time from a management event to colic was 7.5 days (range 2-14 days). Odds ratio for the 15 to 28 days was 1.7 (95% CI=1.0-2.9), odds ratio for 29 to 42 days was 2.1 (95% CI=1.2-3.6). Because management was not clearly associated with a risk period, it was not considered specific and it was insignificant in multivariable analysis. Median time from a bran feeding report to colic was 9 days (range 1-12 days). Odds ratio for 15-28 days was 1.1 (95% CI=0.3-4.3) and 29 to 42 days, OR=3.0, (95%CI=1.3-6.89). Bran feedings that were reported as events were those given as a special addition to the diet and doesn't include bran feedings that were reported as a daily component of the diet. Bran events were eliminated as a significant variable in multivariable analysis.

Colics following foaling occurred at 0, 78, 85, 106, 113, 130, and 138 days (Median=110 days). One of these was fatal due to a gastric rupture, the others were mild. Three colics occurred 43, 66 and 76 days before foaling. Evaluation of colic between 0 days and 60 days post-foaling is hindered by the fact that 29 of the 100 foaling mares left their farm to be bred soon after foaling. Median time from foaling to departure for this group was 8 days (range 3 to 28), and median time off the farm was 81 days (range 36 to 155).

Colic was associated with prior disease for three horses. One horse was reported to have fever, diarrhea and possible founder and was treated with antibiotics and flunixin meglumine for six days prior to the colic episode. The horse was euthanized the day of the colic. One horse had fever, diarrhea and respiratory infection for twelve days with treatment with antibiotics and phenylbutazone before the colic episode. The horse was euthanized nine days after the colic episode. One horse had a history of fever several times at the racetrack over a two month period, fever for two days, and antibiotic treatment before the colic episode. The horse was later diagnosed with a lung abscess. Two disease events, diarrhea and fever were associated with colic. No colics were reported for the time periods after 14 days for either event.

The frequency of the weather events over the 486 days covered by the study and the odds ratios for the weather variables are shown in Tables 6-4 and 6-5. Two weather variables were significant. The risk for colic was increased on the day of snow if snow was greater than a trace (>0.1 inch), OR=3.3 (1.5-6.9). Six colics were associated with two snowstorms in March. Four horses had colic episodes over two days, March 13 and 14, during which there was a total snowfall of 2.0 inches. Two horses had colic March 30 during a 1.5 inch snowfall. A slight increase in colic was associated with low humidity the day before the colic-date, OR=1.7 (1.1-2.5). These colics occurred in all seasons. Risks were slightly elevated if low barometric pressure was noted several days before the colic, but evaluations for increasing or decreasing pressure trends over several days before colic were insignificant.

Eighty-three of the 86 horses with first colic episodes had at least one of the identified risk factors from the final events analysis. Three colics were unexplained by any factor, ten horses had one factor, 25 had two factors, 24 had three factors and 24 had four or more factors. Of the horses with only one identified risk factor, four had high concentrate intake, 4 had history of encephalomyelitis vaccine, 1 recent transport and 1 recent low humidity day.

The most frequently associated factor with horses with colic episodes was high concentrate intake, 70 of the 86 horses (81%) with colic had mid or high levels. History of encephalomyelitis vaccine was associated with 58 of 86 colics (67%), low humidity with 29 of 86 (34%), recent vaccination with 22 of 86 (26%), vices with 21 of 86 (24%), history of colic with 18 of 86 (21%), recent transport with 12 of 86 (14%), foaling 60-150 days with 6 of 86 (7%), snow with 6 of 86 (7%) and fever with 3 of 86 (4%).

Discussion

Demonstration of events or changes as risk factors requires linking the time of an event to disease occurrence, and showing increased risk for a period of time following the event or change. Risk would not be cumulative, and risk would return to the pre-event levels after the time period of increased risk. Analysis of events in relation to a specific time, either a colic-date or a randomly selected date within the observational period for horses without colic was performed. The analysis identified recent vaccination, recent transport, recent fever or diarrhea, the time interval 60 to 150 days after foaling, snow greater than 0.1 inch and humidity less than 50% the previous day as factors associated with increased colic.

Handling time by assigning a date for each horse allowed events to be analyzed with strict attention to the time of increased risk. The random-date represents a time without connection to any event and the demonstration of a odds ratio unequal to one between cases and non-cases implies that the colic-date was related to the event for the horses with colic. The time could have been assigned in three ways: a matched nested case-control where time for cases is based on date of disease occurrence and controls are matched to cases so the date for the control is also the date of disease occurrence, or a case-control, with the controls assigned a random time within the study time either for the whole cohort, or a random sample of controls (unmatched nested case-control or sometimes referred to as case-cohort)[181]. The nested case-control or case-cohort are usually chosen for efficiency reasons, the cost of additional information gathering, analysis or laboratory tests making it desirable to work with a subgroup of the cohort. Since event information was already available for all horses, no advantage was gained from a nested case-control. A matched nested case-control precluded the use of the logistic binomial method for random effects. Matching on the date requires conditional logistic regression which doesn't allow a second matching for farm to handle the random effect. A similar method was used by Grohn in his analysis of the relationships of diseases in Finnish cattle[182,183], however he used randomly assigned disease dates for his non-cases. Another way to handle the farm effect would have been to match for both date and farm. This was not possible since farm and date were sometimes highly confounded; for example, events such as anthelmintic treatment were often done to all the horses on a farm on one day.

Herd effects are an important consideration in veterinary epidemiological studies[161]. Random effects models[154,156,166,167] are used to correct variance estimates that are too small because they are computed based on independent animals rather than animals clustered in herds. Random effects also are thought to control for unmeasured herd variables that could be confounding[162,165]. In the logistic regression analysis done in this study, farm was an important confounder when variables were examined individually, but when multiple variables were analyzed, farm was no longer a significant variable in the analysis. It appears that the multiple variables act together to account for the confounding farm effect. However it was left in the models.

Our results confirmed several previous reports that postulated risk[117,130,142] for the mare post-foaling. Mares were at increased risk (OR=5.0) for colic two to five months after foaling. An increased risk for the time period prior to foaling or immediately following foaling was not demonstrated.

Recent transport was a strong risk factor (OR=2.7). Transport is potentially stressful to the horse because of the possible problems and strange situations that may be involved. In the cohort analysis, horses with a low number of transports (1-6) had higher risk than horses with greater than six transports for the year. Horses with regular transport might become accustomed to the routine and be less stressed.

Vaccination was not anticipated as a risk factor. Vaccination has not been previously associated with colic risk, but in this study vaccination was a strong risk factor (OR=3.4). Interpretation of this finding in this study must be made with caution because it is impossible to separate the effects of the different vaccines administered concurrently. Two possible mechanisms can be postulated; the act of vaccination or the immunological response to vaccination are stressful and the horse responds with alterations in gastrointestinal function or that certain types of vaccines increase risk for colic. Encephalomyelitis, influenza and PHF vaccine factors appear to have the highest odds ratios, these vaccines themselves do not increase risk, rather this variable represents a level of health and use management which is also linked with high levels of concentrate that increases risk for colic. The fact that no one vaccine type consistently shows high risk without other vaccines showing slightly lower risk, suggests that the act of vaccination is more important than the type of vaccine. Administration of multiple vaccines at one time was not associated with increased risk compared to administration of a single vaccine.

No plausible biological explanation for a connection between encephalomyelitis vaccine given in the year before the study and colic can be made. This variable may represent a description of the health program and other untested factors about the horse's management program that have not been better defined by other variables.

Two weather variables were risk factors; greater than 0.1 inches of snow the day of the colic (OR=3.3) and humidity less than 50% the day before the colic (OR=1.7). Weather could cause colic either by directly affecting gastrointestinal function, or indirectly through the interruption of normal management routine for feeding or handling leading to gastrointestinal dysfunction. The association with snow is likely related to management interruptions, although neither snowstorms associated with the colics involved large accumulations. Lack of association of rain greater than 0.1 inch likely rules out gastrointestinal dysfunction mechanisms because the same type of weather system excluding temperature would be expected for either rain or snow. The association of colic with low humidity is relatively weak. A possible mechanism for effect of humidity on gastrointestinal function is unclear.

Weather is a complicated interplay of temperature, pressure, humidity and precipitation factors changing over several days. A clearcut weather-associated risk factor that directly causes colic by influencing gastrointestinal function was not demonstrated.

Increased risk associated with specific feeding changes was not demonstrated, yet the variables relating to level of concentrate fed remained important (OR=6.3 for high levels of concentrate). It appears that the farm management that makes frequent concentrate changes has increased colic risk, but that the risk is not associated with the actual time of the change.

Feeding, exercise and management changes are difficult to measure and subject to under or inconsistent reporting by owners. Events were too few to analyze for more specific categories such as increased levels, decreased levels or special events like water deprivation or other management problems. Events included in the broad management categories may have been too varied to demonstrate associations. Further work is needed to improve definition for these types of events before risk can be ruled out, however the study size required for the statistical power to demonstrate risks may be too large for the studies to ever be accomplished.

The association of colic with diarrhea and fever is very strong. Diarrhea was not included in the logistic regression because there were no exposed non-cases, and the computer program would not fit the model with it included. The number of diarrhea events is very low, but reporting for diarrhea would be expected to be accurate because it is a clearly defined event. Depression was strongly associated, but because it was obviously poorly reported (only 11 events), it was not used in the analysis. Continuing or chronic systemic disease appears to be strongly associated with colic, but was only involved with a small proportion of colics (3/104). Colic in a horse with previous systemic illness had a poor prognosis, 2 of 3 were euthanized.

Of the variables previously identified for the whole cohort, history of colic and increased concentrate feeding levels remained strong risk factors in this event analysis. Feeding whole grains as concentrate decreased risk (OR=0.4) except in the horse with vices and recent transport. A horse being fed whole grains may have lower risk because it has low intensity use and the interactions represent the horses which have more high intensity use. Cribbing was marginally significant in the previous analysis and vices which includes cribbers was moderately significant (OR=1.8) in the event analysis. Age was no longer significant to the analysis, new variables added were more explanatory for the colics that previously had been explained by the age variable.

In previous analysis the risk for a specific event was analyzed in terms of whether the horses with colic had a greater frequency of the events than horses without colic. The time used for measuring the frequency of events was the study year. Events were analyzed along with numerous horse and farm factors. The event count included events occurring before and after the colic episode and was not adjusted for the time the horse was on the study. If events were counted only for the time before the colic episode for the cases, the time for events to occur would be different for cases and non-cases since non-cases would have a full year to accrue events while the colic cases' year would consist only of the time before the colic. Standardization of event numbers by multiplication of a time factor was not done because it would introduce rather than correct for error because events were not regularly spaced throughout the year.

Analysis of variables by a combined cohort and nested analysis allowed the risk factors to be examined for both long term risk and short term risk, according to depending on what attribute is of interest. Nested analysis of events relative to a date rather than by frequency during the study year as in the cohort analysis was more informative for assessing short term risk for events. Association of colic with transport, fever, foaling and weather were detected by this method, but these associations were not indicated in the cohort analysis. PHF vaccination and concentrate and hay event variables appear to have been influenced by events and changes that occurred after the colic episode. Alternately the risk from these factors may not be only associated with the time of the actual change, but more with the cumulative effects of changes over time. The risk for recent vaccination was very strong, but risk was not specific for one vaccine type. An attempt to select one vaccine over the others by logistic regression would be misleading since most vaccines were significant individually. Number of vaccines given, the variable used in the cohort analysis, was not very explanatory. Further study with efforts to separate these effects is necessary to explain this result.

In conclusion, previous colic, high levels of concentrate intake, recent vaccination, recent transport, systemic disease involving fever and/or diarrhea, snow > 0.1 inch, vices, and foaling 60-150 days previously increase the risk of colic. Feeding a whole grain decreased risk compared to the diet without whole grain except for the horse with transport or vices. Weather factors, other than snow were not important risk factors, though low humidity the previous day was weakly associated.

TABLE 6-1 LIST OF EVENTS TO BE REPORTED ON CALENDARS BY OWNERS

Change in diet for a horse or group of horses
Change in the type of feed or new feed
Change in housing, pasture or bedding
Change in exercise or use
Deworming
Medical treatment of any kind
Vaccinations
Transport
Horses leaving the farm
New horses arriving on the farm
Breeding, foaling, weaning
Change in horse's behavior
Any individual horse or herd infections
Injury or trauma to any horse
Visits by the dentist, farrier or veterinarian

TABLE 6-2 FREQUENCY OF EVENTS REPORTED ON CALENDARS

Table 6-2 Event Frequency	Number of events reported	% Farms reporting at least 1 event (/31)	% Horses with at least 1 event(/1427)	Median number of events for horses with event(range)
Specific Health events:				
Depression	11	11(35%)	11(0.8%)	1(1)
Diarrhea	10	6(19%)	10(0.7%)	1(1)
Fever	77	16(52%)	51(4%)	1(1-5)
Injury	176	25(81%)	134(9%)	1(1-5)
Lameness	143	25(81%)	105(7%)	1(1-4)
Respiratory disease	104	17(55%)	81(6%)	1(1-4)
Vaccination: all	3063	31(100%)	1058(74%)	2(1-11)
Tetanus	701	27(87%)	618(43%)	1(1-4)
Encephalomyelitis	600	23(74%)	499(35%)	1(1-3)
Rhinopneumonitis	1611	28(90%)	809(57%)	2(1-7)
Strangles	232	6(19%)	167(12%)	1(1-4)
PHF	873	27(87%)	612(43%)	1(1-4)
Rabies	390	16(52%)	357(25%)	1(1-3)
Influenza	1610	29(94%)	848(59%)	1(1-7)
Other (botulism, rotavirus)	100	7(23%)	74(5%)	1(1-4)
Anthelmintic treatments	3812	31(100%)	1250(88%)	3(1-9)
Farrier	5185	31(100%)	1113(78%)	4(1-18)
Transport	2251	31(100%)	812(57%)	1(1-37)
All health events:		31(100%)		4(1-98)
Veterinarian visit	2713	31(100%)	851(60%)	2(1-17)
Treatment: all	3166	30(97%)	530(37%)	3(1-73)
Drug	2956	28(90%)	511(36%)	3(1-75)
Non-drug	332	28(90%)	170(12%)	1(1-10)
Routine	1347	30(97%)	656(46%)	2(1-12)
Diagnostic	1124	30(97%)	454(32%)	2(1-12)
Surgical	104	18(58%)	82(6%)	1(1-3)

Table 6-2 Event Frequency	Number of events reported	% Farms reporting at least 1 event (/31)	% Horses with at least 1 event(/1427)	Median number of events for horses with event(range)
Health events by body system:				
Reproductive	638	24(77%)	212(15%)	2(1-17)
Gastrointestinal (other than colic)	114	15(48%)	41(3%)	2(1-22)
Skin	452	25(81%)	131(9%)	2(1-25)
Respiratory	392	25(81%)	104(7%)	2(1-16)
Musculoskeletal, nervous and hoof	1370	29(94%)	285(20%)	3(1-50)
Dental	375	18(58%)	311(22%)	1(1-4)
Non-specific inflammation	471	21(68%)	131(9%)	2(1-22)
Routine, general	734	30(97%)	508(36%)	1(1-12)
Eye	76	14(45%)	28(2%)	2(1-11)
Other	161	16(52%)	59(4%)	1(1-52)
Unknown	1608	28(90%)	378(26%)	1(1-35)
Exercise change	2574	21(68%)	316(22%)	2(1-183)
Nutrition change		31(100%)		
Concentrate	664	20(65%)	316(22%)	1(1-15)
Hay	681	17(55%)	371(26%)	1(1-5)
Bran	614	29(94%)	215(15%)	1(1-10)
Additive	274	15(48%)	168(12%)	1(1-5)
Management change	3848	29(94%)	778(55%)	3(1-133)
Housing(stable, pasture, paddock)	2965	26(84%)	603(42%)	2(1-131)
Farm maintenance	456	7(23%)	199(14%)	2(1-6)
Horse maintenance	110	12(39%)	105(7%)	1(1-3)
Unusual happening	68			
Breeding associated	249	14(45%)	175(12%)	1(1-27)
Breeding	100	12(39%)	61(0.4%)	1(1-10)
Foaling	98	16(52%)	98(7%)	1(1)
Weaning	200	13(42%)	200(14%)	1(1)

TABLE 6-3 ODDS RATIOS FOR EVENTS

Table 6-3 Events * Used in logistic regression	#events within 14 days of colic (/86)	# events within 14 days of random-date (/1341)	Odds ratio (95% confidence interval)	p-value
Housing and pasture:				
Arrival on farm (new or return)	5(0.06)	41(0.03)	2.0(0.6-5.1)	0.19
Change in stable, pasture or paddock	12(0.14)	112(0.08)	1.8(0.9-3.5)	0.07
Use:				
Exercise	7(0.08)	64(0.05)	1.8(0.7-4.0)	0.13
Transport*	12(0.14)	58(0.04)	3.6(1.7-7.3)	0.0000
Farrier	19(0.22)	258(0.19)	1.2(0.7-2.1)	.52
Breeding	0	4(0.003)		
Foaling				
0-14 days	1(0.01)	6(0.004)	2.6(0.1-21.9)	0.35
60-150 days*	6(0.07)	27(0.02)	3.7(1.2-9.4)	0.01
0-90 days before	3(0.03)	17(0.01)	2.8(0.5-10.0)	0.11
Weaning	1(0.01)	16(0.01)	1.0(0.02-6.4)	1.00
Management change:				
All types*	18(0.21)	157(0.12)	2.0(1.2-3.1)	0.310.
Farm maintenance*	5(0.06)	25(0.02)	3.3(1.0-8.9)	03
Horse maintenance	1(0.01)	6(0.004)	2.6(0.1-21.9)	0.35
Unusual happening	0			
Breeding associated	1(0.01)	16(0.01)	1.0(0.02-6.4)	1.0
Nutrition change:				
Concentrate	3(0.03)	30(0.02)	1.6(0.3-5.2)	0.45
Hay	2(0.02)	29(0.02)	1.1(0.1-4.4)	0.71
Bran*	7(0.08)	36(0.03)	3.2(1.2-7.6)	0.01
Additive	2(0.02)	12(0.01)	2.6(0.3-12.1)	0.20
Specific Disease events:				
Depression*	1(0.01)	2(0.001)	7.9(0.1-152)	0.17
Diarrhea*	2(0.02)	0		0.000.
Fever*	3(0.03)	3(0.002)	16.1(2.1-122)	00
Injury	0	9(0.007)		
Lameness	2(0.02)	11(0.008)	2.9(0.3-13.5)	0.18
Respiratory disease	0	3(0.002)		

Table 6-3 Events * Used in logistic regression	#events within 14 days of colic (/86)	# events within 14 days of random-date (/1341)	Odds ratio (95% confidence interval)	p-value
Health Management Events:				
Vaccination: All types*	22(0.26)	120(0.09)	3.5(2.0-6.0)	0.00
Tetanus	8(0.09)	46(0.03)	2.9(1.2-6.6)	0.01
Encephalomyelitis	9(0.10)	32(0.02)	4.8(2.0-10.9)	0.00
Rhinopneumonitis	10(0.12)	69(0.05)	2.4(1.1-5.1)	0.01
Strangles	3(0.03)	8(0.006)	6.0(1.0-25.6)	0.02
PHF	10(0.12)	46(0.03)	3.7(1.8-5.9)	0.00
Rabies	3(0.03)	28(0.02)	1.7(0.3-5.7)	0.40
Influenza	12(0.14)	71(0.05)	2.9(1.4-5.8)	0.00
Other (botulism, rotavirus)	0			
Anthelmintic administration(all types)	15(0.17)	195(0.15)	1.2(0.7-2.3)	0.21
Health event: All types*	18(0.21)	166(0.12)	1.9(1.1-3.3)	0.02
Drug*	10(0.10)	81(0.06)	2.0(1.0-4.3)	0.04
Non-drug	2(0.02)	18(0.01)	1.8(0.2-7.5)	0.34
Routine	5(0.06)	59(0.04)	1.3(0.4-3.4)	0.59
Diagnostic	4(0.05)	40(0.03)	1.6(0.4-4.6)	0.33
Surgical	1(0.01)	4(0.002)	3.9(0.1-40)	0.27
Health events by body system:				
Reproductive				
Gastrointestinal*	3(0.03)	16(0.01)	3.0(0.6-10.8)	0.10
Skin	2(0.02)	1(0.001)	31.9(1.6-1883)	0.01
Respiratory	3(0.03)	14(0.01)	3.4(0.6-12.6)	0.08
Musculoskeletal, hoof	1(0.01)	8(0.006)	2.0(0.04-14.9)	0.43
or nervous	3(0.03)	30(0.02)	1.6(0.3-5.2)	0.45
Dental				
Non-specified	2(0.02)	28(0.02)	1.1(0.1-4.6)	0.70
inflammation	2(0.02)	12(0.009)	2.6(0.3-12.1)	0.20
Routine				
Eye	1(0.01)	32(0.02)	0.5(0.01-3.0)	0.72
Other	0	1(0.001)		
Unknown	0	5(0.004)		
	5(0.06)	43(0.03)	1.9(0.6-4.9)	0.21

TABLE 6-4 WEATHER EVENTS

Table 6-4 Weather Events	Number of days/486	Number of colics/104
High Daily Temperature (°F)		
<=30	8	0
<=40	35	8
<=50	100	15
<=60	82	17
<=70	71	16
<=80	69	12
<=90	77	23
<=100	44	13
Low Daily Temperature (°F)		
<=10	11	0
<=20	37	5
<=30	120	28
<=40	84	13
<=50	73	14
<=60	73	8
<=70	73	32
<=80	15	4
Precipitation (Rain and Snow)(inches)		
None	294	63
<=0.1	99	21
<=0.2	32	8
<=0.3	11	0
<=0.4	5	2
<=0.5	8	0
<=1	26	7
>1	12	3
Snow (inches)		
None	456	98
Trace	19	1
>=0.1	11	5
Rain (inches)		
None	294	63
<0.1	102	24
<0.5	59	12
<1.0	26	4
>1.0	5	1

Table 6-4 Weather Events	Number of days/486	Number of colics/104
Humidity at 10 AM (%)		
<=40	25	3
<=50	87	19
<=60	131	35
<=70	87	20
<=80	47	12
<=90	49	9
<=100	49	6
Barometric Pressure (mm Hg)		
<=29.0	3	0
<=29.25	4	1
<=29.5	62	18
<=29.75	205	51
<=30.0	163	30
>30.0	50	4

TABLE 6-5 ODDS RATIOS FOR WEATHER EVENTS

Table 6-5 Odds Ratios for Weather Events	Number Exposed		Odds Ratio (95% CI)	* p <= 0.05
	with colic/86	without colic/134		
High Temperature < 40°F				
day 0	6(0.07)	58(0.04)	1.7(0.6-4.0)	
day 1	2(0.02)	44(0.03)	0.7(0.1-2.8)	
day 2	0	57(0.04)		
High Temperature < 50°F				
day 0	20(0.23)	250(0.19)	1.3(0.7-2.3)	
day 1	16(0.19)	246(0.18)	1.2(0.6-1.8)	
day 2	21(0.24)	257(0.19)	1.4(0.8-2.3)	
High Temperature > 79°F				
day 0	32(0.37)	481(0.36)	1.1(0.7-1.7)	
day 1	29(0.34)	486(0.36)	0.9(0.6-1.5)	
day 2	33(0.38)	482(0.36)	1.1(0.7-1.8)	
High Temperature > 89°F				
day 0	12(0.14)	192(0.14)	1.0(0.5-1.9)	
day 1	14(0.16)	190(0.14)	1.2(0.6-2.2)	
day 2	14(0.16)	199(0.15)	1.1(0.6-2.1)	
Difference between High and Low Temperature < 25°F				
day 0	55(0.64)	733(0.55)	1.5(0.9-2.4)	
day 1	48(0.56)	685(0.51)	1.2(0.8-1.9)	
day 2	51(0.59)	729(0.54)	1.2(0.8-2.0)	
Difference between High and Low Temperature > 40°F				
day 0	1(0.01)	21(0.02)	0.7(0.02-4.7)	
day 1	0	16(0.01)		
day 2	1(0.01)	24(0.02)	0.7(0.02-4.1)	
Low Temperature < 20°F				
day 0	3(0.03)	79(0.06)	0.6(0.1-1.8)	
day 1	3(0.03)	69(0.05)	0.7(0.1-2.1)	
day 2	1(0.01)	86(0.06)	0.2(0.03-1.0)	
Low Temperature < 32°F				
day 0	30(0.35)	370(0.28)	1.4(0.9-2.3)	
day 1	26(0.30)	388(0.29)	1.1(0.6-1.8)	
day 2	23(0.27)	383(0.29)	0.9(0.6-1.5)	
Low Temperature > 60°F				
day 0	27(0.31)	347(0.26)	1.3(0.8-2.2)	
day 1	26(0.30)	326(0.24)	1.3(0.9-2.2)	
day 2	23(0.27)	354(0.26)	1.0(0.6-1.7)	

Table 6-5 Odds Ratios for Weather Events	Number Exposed		Odds Ratio (95% CI)	* p <= 0.05	
	with colic/86	without colic/134			
Precipitation > 0.1 inch					
day 0	19(0.22)	265(0.20)	1.2(0.7-2.0)		
day 1	17(0.20)	269(0.20)	1.0(0.6-1.7)		
day 2	18(0.21)	244(0.18)	1.2(0.7-2.1)		
Precipitation > 1 inch					
day 0	3(0.03)	27(0.02)	1.8(0.3-5.9)		
day 1	1(0.01)	30(0.02)	0.5(0.01-3.2)		
day 2	1(0.01)	30(0.02)	0.5(0.01-3.2)		
Rain					
day 0	32(0.37)	544(0.41)	0.9(0.5-1.4)		
day 1	30(0.35)	542(0.40)	0.8(0.5-1.3)		
day 2	30(0.35)	511(0.38)	0.9(0.5-1.4)		
Snow					
day 0	6(0.07)	76(0.06)	1.3(0.4-3.0)		
day 1	2(0.02)	66(0.05)	0.5(0.1-1.8)		
day 2	2(0.02)	59(0.04)	0.5(0.1-2.0)		
Snow > 0.1 inch					
day 0	6(0.07)	26(0.02)	3.8(1.2-9.8)	*	0.01
day 1	2(0.02)	21(0.02)	1.5(0.2-6.3)		
day 2	1(0.01)	15(0.01)	1.0(0.02-6.9)		
Humidity < 50%					
day 0	19(0.22)	311(0.23)	0.9(0.5-1.6)		
day 1	29(0.34)	307(0.23)	1.7(1.1-2.8)	*	0.02
day 2	28(0.33)	318(0.24)	1.6(1.0-2.5)		
Humidity > 80%					
day 0	14(0.16)	291(0.22)	0.7(0.4-1.3)		
day 1	14(0.16)	277(0.21)	0.8(0.4-1.4)		
day 2	16(0.19)	278(0.21)	0.9(0.5-1.6)		
Humidity > 50% and High Temperature > 70°F					
day 0	36(0.42)	558(0.42)	1.0(0.6-1.6)		
day 1	31(0.36)	568(0.42)	0.8(0.5-1.2)		
day 2	32(0.37)	569(0.42)	0.8(0.5-1.3)		

Table 6-5 Odds Ratios for Weather Events	Number Exposed		Odds Ratio (95% CI)	* p <= 0.05
	with colic/86	without colic/134		
Barometric Pressure <29.5 mm Hg				
day 0	12(0.14)	157(0.12)	1.2(0.6-2.4)	
day 1	14(0.16)	135(0.10)	1.7(0.9-3.3)	
day 2	13(0.15)	132(0.10)	1.6(0.8-3.1)	
Barometric Pressure <29.75 mm Hg				
day 0	55(0.64)	798(0.60)	1.2(0.8-2.0)	
day 1	57(0.66)	795(0.59)	1.4(0.8-2.2)	
day 2	55(0.64)	751(0.56)	1.4(0.9-2.3)	
Barometric Pressure > 30.0 mm Hg				
day 0	3(0.03)	116(0.09)	0.4(0.1-1.2)	
day 1	3(0.03)	101(0.08)	0.4(0.1-1.4)	
day 2	4(0.05)	109(0.08)	0.6(0.1-1.5)	
Barometric Pressure decreasing				
last 3 days	44(0.51)	653(0.49)	1.1(0.7-1.8)	
last 1 day	41(0.48)	682(0.51)	0.9(0.6-1.4)	
Barometric Pressure increasing				
last 2 days	35(0.41)	536(0.40)	1.0 (0.7-1.6)	

TABLE 6-6 LOGISTIC REGRESSION ANALYSIS FOR EVENTS

Variable	Beta-coefficient	Standard Error	p-value	Odds Ratio (95% Confidence Interval)
% Grand Mean	-3.48	0.23	<0.001	0.3 (0.2E-01-0.5E-01)
Post-Foaling 60-150 days	1.78	0.52	<0.001	5.9 (2.1-16.5)
Recent Vaccination	1.19	0.30	<0.001	3.3 (1.8-5.9)
Recent Transport	1.18	0.39	0.003	3.2 (1.5-7.0)
Recent Fever	2.42	1.01	0.02	11.3 (1.5-82)
Snow	1.01	0.54	0.06	2.8 (1.0-7.9)
Low Humidity	0.49	0.26	0.06	1.6 (1.0-2.7)
%SCL	0.65	0.19		

TABLE 6-7 COMBINED LOGISTIC REGRESSION ANALYSIS FOR COHORT AND NESTED DATE ANALYSIS

Variable	Beta-coefficient	Standard Error	p-value	Odds Ratio (95% Confidence Interval)
%Grand Mean	-5.10	0.63	<0.001	0.60E-02 (.2E-02-.2E-01)
Transport within 14 days	0.57	0.46	0.22	1.8 (0.7-4.3)
Vaccination within 14 days	1.26	0.30	<.001	3.5 (2.0-6.3)
Foaling within 60-150 days	1.62	0.52	0.002	5.0 (1.8-13.8)
Fever within 14 days	2.70	1.19	0.02	14.8 (1.5-151)
History of colic	1.43	0.34	<0.001	4.2 (2.2-8.0)
Concentrate Dry matter intake				
>0, <2.5 kg/day	1.07	0.67	0.11	2.9 (0.8-10.9)
2.5-5 kg/day	1.73	0.63	0.006	5.6 (1.6-19.5)
>5 kg/day	1.97	0.63	0.002	7.1 (2.0-24.8)
Whole Grain in diet	-2.05	0.57	<0.001	0.1 (0.04-0.4)
History of encephalomyelitis vaccine in year before the study	0.57	0.26	0.03	1.8 (1.1-2.9)
Vice	0.25	0.34	0.47	1.3 (0.7-2.5)
Grain X Vice	2.05	0.79	0.009	7.7 (1.7-36)
Grain X Recent Transport	2.23	1.05	0.03	9.3 (1.2-73)
Snow	0.87	0.55	0.12	2.4 (0.8-7.0)
Low Humidity	0.54	0.26	0.04	1.7 (1.00-2.85)
% SCL	0.96E-15	0.29		

TABLE 6-8 COLICS ASSOCIATED WITH VACCINATION: Vaccines: TET=Tetanus, RAB=Rabies, PHF=Potomac Horse Fever, FLU=Equine Influenza, RHINO=Rhinopneumonitis, EWE=Encephalomyelitis combination, STR=Strangles,

Days between event and colic	Number of vaccines given	Types vaccines given
1	1	STR
3	2	EWE,TET,
3	1	PHF
3	3	EWE,FLU,RHINO
4	1	RHINO
4	1	TET
4	2	EWE,TET
5	2	FLU,RHINO
5	4	EWE
6	3	FLU,PHF,RHINO
7	1	PHF
8	6	TET
9	4	EWE
9	3	EWE,FLU,RHINO
9	4	EWE
10	2	FLU,RHINO
12	3	TET
12	2	FLU,RHINO
12	1	PHF
13	1	PHF
13	1	RHINO
14	5	EWE

Chapter 7

General Discussion

Analysis

The objectives of this study were to estimate incidence of colic and evaluate farm, horse, nutritional, management, event, and weather factors on the risk of developing colic in a randomly selected population of horses from farms. Colic risk factors were analyzed in two ways, a cohort analysis and a nested event analysis. Variables were assessed individually by univariate analysis and then in a multivariable random effects logistic regression. The nested event analysis allowed the event data to be evaluated for the time of risk immediately after the event.

The cohort analysis was done by standard methods for follow-up density data for chronic disease[151,152]. Egret software (Statistics and Epidemiology Research Corporation, Seattle, WA) allowed farm to be included as a random effects variable to account for herd effects. Exposure variables describing characteristics of the horse and its management were measured at the initiation of the study period. Most fixed variables such as breed, nutritional, and management descriptions that remained constant for the horse over the study year were effectively evaluated by this method. However, some characteristics were of interest that changed during the year because of management decisions or seasonal factors. Also specific events that occurred routinely or in response to problems were postulated to have a short term effect on colic risk. The owner was instructed to record events and changes on a calendar. A list with specific events was provided along with instructions to record any changes from the original diet, exercise, housing, pasture and management descriptions. In the cohort analysis, specific events and changes were categorized by the frequency of events for the study year, the only time for which the information was available. But since the study year was also the time when colic incidence was being measured, the event count included events occurring before and after the colic episode. If events were counted only for the time before the colic episode for the cases, the period of risk would be shorter for horses with colic than horses without colic, because horses without colic had a full year to accrue events while the colic cases had only the time before the colic episode. Standardization of event numbers by multiplication by a time factor was not done because it would have introduced rather than corrected error because events were not regularly spaced throughout the year. Correcting counts for horses not on the study for the full year would have had the same problem.

Significant factors from the cohort analysis were level of concentrate dry matter, history of colic, receiving whole grain as feed, age and three event or change variables: multiple concentrate type and amount changes, greater than one change of hay in the year, and PHF vaccination during the year. The weakness of this analysis was the time sequence of event preceding disease can be questioned. Review of significant factors for cases shows that some events did occur after the colic episode.

No successful method for exposure categorization could be devised to improve these variables using the cohort approach. One method tried was to divide each horse's time on the study into exposed time within 14 days of the event and unexposed time not related to the event. The incidence density ratio was computed comparing the number of colics occurring during exposed time to number of colics occurring during unexposed time, but this led to a very unbalanced IDR because unexposed time was so large.

A nested analysis or ambi-directional study [151], referred to as the date analysis, was developed based on epidemiologic methods for acute disease. Events were analyzed in relation to a specific time, either a colic-date or a date within the study time, selected at random for horses without colic. Handling time by assigning a date for each horse allowed events to be analyzed with strict attention to the time of expected increased risk. The random-date represented a time without connection to any event. The odds for the horse without colic was the expected odds for the event if no association existed between the event and the date. The size of this odds was dependent on characteristics of the event, whether many horses would have experienced the event, and how many times per year the event occurred for an individual horse. The demonstration of an odds ratio unequal to one between cases and non-cases implied the colic-date was associated with the event for the horses with colic. The date analysis identified recent vaccination, recent transport, recent fever or diarrhea, the time period 60 to 150 days after foaling, snow greater than 0.1 inch and humidity less than 50% the previous day, were associated with increased colic. Events identified in the cohort analysis, PHF vaccination, multiple concentrate changes and multiple hay changes variables were not significant. For these variables, event frequency may have been influenced by changes that happened after the colic or alternatively the period of risk not closely linked to the timing of the actual event. Risk may have been associated with accumulated risk or other characteristics of the horses that these variables represent other than time.

Most cohort studies do not deal with acute disease risk factors and short periods of risk, but a nested case-control[181] was adapted to make time comparable between horses with colic and horses without colic. The time could have been assigned in three ways: 1) a matched nested case-control where time for cases is based on date of disease occurrence and controls are matched to cases so the date used for a control is also the date of disease occurrence, 2) a case-cohort, with a random sample from the horses without colic as the controls (unmatched nested case-control), with controls assigned a random date within the study time [184], or 3) a case-cohort using the remainder of the cohort without colic as controls, with controls assigned a random date within the study time. The nested case-control or case-cohort are usually chosen for efficiency reasons, the cost of additional information gathering, analysis or laboratory tests makes it desirable to work with a subgroup of the cohort. In this analysis, the whole cohort was used, since event information was already available for all horses. The element of the case-control methodology that is retained was that the point of analysis was backward from the colic-date (or random-date) to the exposure event. A similar method was used by Grohn[182] in his analysis of the relationships of metabolic and reproductive diseases in Finnish dairy cattle. He used the entire cohort, however he used randomly assigned case disease dates for his cows without the disease being studied and did not use a method to account for herd.

Other methods such as a matched nested case-control precluded the use of the logistic binomial method for random effects. Matching on the date requires conditional logistic regression which does not allow a random effect to be included. Another way to handle the farm effect would have been to match for both date and farm and not use a random effect method at all. This was not possible since farm and date were sometimes highly confounded, events such as anthelminthic treatment were often done to all the horses on a farm on one day. Using farm as a fixed effect was not workable, because logistic analysis would not handle efficiently 30 dummy variables required to describe farm (n=31).

Nested analysis of events relative to a date rather than by frequency during the study year selected variables not selected in the cohort analysis. Association of colic with transport, fever, foaling and weather were detected by this method but were not indicated in the cohort analysis. The strength of the date method was its reliance on the random assignment of dates to the horses without colic to represent time not associated with any event. This allowed an odds ratio to be computed for the short segment of time before the colic, without having to deal with the large amount of follow-up time for the whole study. The sensitivity of the analysis was increased, several event variables were significant in the event analysis that were not significant in the cohort multivariable analysis. The temporal sequence of event before colic is assured. Additionally specificity of risk to the time period 14 days before the colic episode could be established by comparison with time intervals earlier than 14 days before the colic. A drawback of the method was because the random-dates were selected randomly there was probability involved in the estimate of risk for the unexposed group. There should be no bias in date assignment because random numbers were used. If comparisons were repeated with a second random-date assignment, results would be expected to be similar but not exactly the same. Exposure status in the study for a horse is linked to the assigned date and must be discussed in terms of the date analysis. Descriptions that involved exposure to events for a horse such as attributable risk are not meaningful within this exposure definition. For example, all horses present on the farms were exposed to the snowstorms, but only those with a random-date within 14 days after the snowstorm were called exposed in the analysis.

Possibility of Error and Bias

In a study such as this when many variables are analyzed, the possibility of type I error, a comparison being significant by chance alone, needs to be considered.

While each comparison has a 5% chance of being significant by chance, the chance of type I error was not related to the number of variables evaluated[185]. The possibility of type I error for each significant association should be evaluated on its own merit, the variable's prior credibility, biological plausibility, and potential selection or measurement biases.

The possibility of type II error, the finding of no association when a true association exists, must be considered for several parts of this study. In spite of the number of associations detected in this study, certain significant factors may have been missed. Power for variables evaluated at the farm-level was limited due to the low number of farms and the multiple categories being evaluated for some variables. This study may not have had the sensitivity to detect an association with colic for events occurring infrequently. A larger population size or alternative study design would be needed to demonstrate association for rare events.

Cohort and date analyses could have been affected by variation between farms in reporting or underreporting for the event variables that describe change. Owners were to report on calendars when a horse had a change from the original profile information for nutrition, exercise, housing, use and management. Because interpretation of a change was left to the owner, calendar entries were variable, some owners giving much detail and some owners few details. In retrospect the calendars should have been used only for specifically defined events for which the owners would have similar interpretation. The list of events to report should have been expanded to include more exercise, nutrition and management events that occur on a definite date. For exercise these might have included: show, hunt, race, trial, event, use or ride of unusual intensity, start training for a particular purpose, start breaking, start rest or stop training. For nutrition these might have included: start or stop a new type of concentrate or additive, start or stop pasture, special bran feeding, missed feeding, no water for longer than a specific time, or start hay from a new year. For management these might have included: barn maintenance (painting, reflooring, vermin control), starting increased light intervals to induce reproductive cycling, changing stalltime, changing pasture or stall location, and unusual events like horses getting out through an open gate.

Events classified in the same category needed to be closely related. Some variables for management, housing and pasture, exercise and nutrition changes may have included too wide a variety of changes. In these categories, risk for a specific change might not have been detected if the risk was diluted by the effects of changes without risk. Some events that occur regularly, daily, every few days or weekly for most horses should be excluded from date analysis since most owners tended not to report these as important events. An example of this was horse related management events reported like grooming and bathing. However if events were too specifically defined, the events would be too infrequent for meaningful analysis in a study of this size. In this study the lack of power to detect a difference became an important consideration in that confidence intervals became extremely wide for events reported less than 100 times for the whole cohort.

Exercise and nutritional change measurement could be improved by using a short form of the profile questionnaire at each three month visit. This would allow this type of category to be used in the cohort type analysis. Descriptive variables could be defined for the level of exercise, housing and pasture and nutrition changes over the year without having to rely on owner consistency and uniformity of calendar entries. Using a computer printout of the original information as a baseline, the owner would be asked for changes in the diet, stable and pasture times, and exercise schedule for each horse five times during the study, the start and each three month visit. The investigator could then classify the horse into categories, that describe the level of change for these variables; no change over the year, seasonal change, increase, decrease, or variable throughout the year.

Analysis for risk factors should ideally identify a sub-group of horses with several factors that act together to elevate risk for colic. This group was postulated to be related to a use category that involved a certain type of feeding strategy, exercise regimen, health program and performance demands. Nutritional risk factors and factors related to health were identified, but exercise and use variables were not explanatory. Defining exercise levels is not an easy task, either in human studies or horse studies, as it is dependent on type, regularity, and intensity. These variables can not be conclusively ruled out without further examination. Use type was defined by the owner and may have included horses not actively being used for that stated use, such as horses intended for the purpose in the future or horses used for the purpose in the past. Eleven use categories were used, which may have not been enough to cover the variability, but may have been too many to work well in the logistic regression. Risk associated with low intensity uses, lessons or pleasure riding, appeared to be less than for higher intensity uses such as training and eventing, but was not a selected variable in the logistic regression analysis. Exercise was originally analyzed in terms of hours per day or hours per week of work. The work variable was non-significant even in univariate analysis. A better measure of work would have been attained if work was broken down into three variables, 1) length of work during one session, such as an one hour work-out/day or four hours of lessons/day, 2) intensity of work: such as light, moderate or hard, and 3) regularity of work, such as daily (5 or more days a week), occasionally (one to four days a week) or infrequently (less than once a week). Groupings that reflect level of work and cut across use categories may be more informative.

Another area where the variable measurement could have been improved was the farm management information from the farm questionnaire. Even when owners were given predefined categories on the farm questionnaire, given answers did not fit into one category, the answer was different for different horses on the same farm. Horse management choices appear to be made on the individual horse level or for groups of horses on the farm used for like purposes. For these variables, analysis on the horse level would be more appropriate and informative than on the farm-level.

Reliable measures of hay intake and pasture intake were considered beyond the scope of this study. Measurement of amount of hay fed to horses were inexact and did not describe how much the horse actually consumed. Pasture intake could only be estimated from time spent on pasture and would be influenced by seasonal availability of forage. No attempt was made to make these estimates. This information was necessary for a complete nutritional assessment of a horse's diet, therefore no conclusions concerning the adequacy of the nutritional status of the horses for their intended use or relative to their colic risk were made from this study.

Incidence

The population based incidence density of colic measured in our study, 10.6 colic cases per 100 horse-years, was slightly higher than practice based incidence reported by Rollins and Clement (9%)[15], Foreman and White (6%)[17] and Barrett et al. (7%)[18]. Since 68% of the colic cases in this study were treated by a veterinarian, this figure adjusted as a practice based estimate would be comparable (7%). Colic incidence in this population was lower than population based incidence measured by Uhlinger[19] for 14 non-randomly selected herds. The use of a random selection method to select farms in this study decreased the possibility of selection bias. Selection factors related to geographical area, farm size and owner's willingness to participate are shared by most studies using horse herds.

No other population based mortality studies are available for horses. Mortality from all causes in this population was 2.5 deaths per 100 horse-years. Proportional mortality of colic was 28%, the highest for any one cause. Several frequency studies rank colic as one of the most important equine health problems[4,16], and this study confirmed those results.

The types of colic lesions and the case fatality rates reported in this study reflected that more mild colic cases (75%) occurred than indicated in studies using hospital cases. Undefined colic (84) and gas colic (4), (85%), together form the category comparable to the 25% undefined colic in White's study[3] of colic cases at 14 university hospitals. Numbers were low, but the relative distribution of obstruction, 11% (9 obstruction-impaction and 2 gastric rupture); strangulation, 4% (3 strangulation and 1 torsion); and enteritis, 1% (1); was similar to White's hospital study distribution: obstruction (35%), strangulation (21%), and enteritis (6%). Case fatality was 6.7% in this study.

Risk Factors

Parasites were not found to be a significant risk factor in this study. None of the variables related to parasite control were significant in the multivariable analysis. History of no anthelmintic use for adult horses in the year before the study was significant in the univariate analysis, but not when examined in the multivariable analysis. The number of horses without any parasite control was small, 2% in 1990 according to questionnaire history and 7% in the study year 1991 according to reported deworming events. No relationship between farm incidence density and proportion of parasite egg positive fecal samples was indicated for 15 samples per farm taken over three seasons. While no evaluation of the effectiveness of parasite controls program for horses receiving anthelmintic treatments can be made, there was no indication of an association between colic and parasite infection in this population. This does not mean that parasites do not cause colic, but that for this population the role of parasites in the colics reported was not detectable.

This prospective study documented two previously postulated risk factors for equine colic, the risk for the horse with a history of colic and post-foaling risk for the mare. Several authors[7,98,127] discuss previous colic as important history in evaluating a colic patient. History of colic was a strong risk factor in this study, present in 18 (21%) of the colics.

The risk for colon torsion or volvulus in the mare with a young foal was discussed by Huskamp[117], Fischer[142] and Snyder[130]. Variables related to breeding, foaling and gender were not important in this cohort analysis. When periods of time in relation to foaling were assessed in the nested date analysis, a significant cluster of 6 colics was demonstrated in mares between 60 and 150 days post foaling. This time corresponds to the time of lactation when the mare requires high energy and high protein intakes to produce milk. A high protein, energy dense concentrate is recommended at 1-2% of body weight during early lactation (1-12 weeks) and 0.5-

1.5% during late lactation (13-24 weeks)[175], in addition to quality forage. High level and certain types of concentrate intake were significant risk factors in this study for all horses and may be important in the lactating mare. Possibly the horses were being over-supplied energy or the type of concentrates used were not optimal for the mare's increased needs. The time of risk corresponds to when the foal is beginning to creep feed and the mare's milk production demands would be expected to begin to lessen. The risk for the mare may be related to the level of concentrate feeding not being adjusted as concentrate requirements decrease. Huskamp has speculated that availability of new lush spring pasture is a factor. Although this was not evaluated in relation to the mares with colic, variables related to forage examined for all horses were not significant and give no support to this hypothesis. Further comparison of diet, forages, concentrates and forage/concentrate balance in a larger group of lactating mares might resolve the role of these dietary components as important risk factors in this subgroup.

Variables related to concentrate intake, the level, type, and frequency of feeding were strong risk factors. Horses on pasture receiving no concentrates and young horses less than two years old had the lowest risk of colic. As the amount of concentrate was increased in the diet the risk for colic increased. Attributable fraction, the proportion of colic in the exposed horses that can be attributed to the exposure[186], was 84%, for the highest level of concentrate intake (>5 kg/day), and 79% for the mid level concentrate intake (2.5-5 kg/day). Concentrate intake level was a major contributing factor to the number of colics in this population because a large number of horses were being fed diets with concentrate at levels associated with significant risk, 426 horses (30%) for the highest level and 433 horses (30%) for the mid-level. Concentrate intake level and type are two factors that can be altered to decrease a horse's risk for colic. Frequency and level of concentrate were collinear, highly associated with each other, so that fixing the level of concentrate meant that nearly all horses were in the same frequency category[174]. However, it appears that feeding high amounts of concentrate in 3 or more feedings a day did not reduce the risk associated with high levels of concentrate being fed. Based on the attributable risk and the large number of horses with this risk factor, changing concentrate feeding management practices should have a major impact to decrease the incidence of colic. The recommended intake of concentrate for maintenance requirement of a mature 500 kg horse is 0 to 0.5% of body weight[175] or up to 2.5 kg/day concentrate. The level of concentrate would need to be adjusted upward to meet individual requirements for the larger horse, lactating mares and horses in moderate or intense work. However, by reducing the concentrate to levels below 2.5 kg/day, in this study, 38 colics in the high-level intake and 29 colics in the mid-level intake categories would have prevented. If reducing concentrate was considered independently, the study incidence density would be estimated to decrease from 10.6 to 3.7 colic cases per 100 horse-years, a 65% reduction in colic.

Mechanisms suggested by Clarke[12] regarding fluid shifts, motility patterns and cycles in microflora fermentation associated with low-forage diets would apply to horses receiving high levels of concentrate. The risk of colic associated with concentrate is also related to type of concentrate. Feeding a whole grain as part of the diet decreased risk except for the horse with transport or vices. Sweetfeed and pellet were both associated with increased risk, sweetfeed having a slightly higher odds ratio. One-half of the horses in the study were being fed diets containing concentrates, 217 received pellets and 496 received sweetfeed, which increased their risk for colic. Further evaluation of specific feeds relative to energy content, soluble carbohydrate versus insoluble carbohydrate content, simple sugar versus complex carbohydrate content, and digestibility may add to our understanding of the differences involved. More processed feeds like pellets or feeds with added readily available energy sources such as molasses in sweetfeeds may move through the upper digestive tract more rapidly and may be digested more easily by microflora in the large bowel. Bursts of fermentation lead to increased colonic osmotic pressure resulting in shifts of fluids to the large colon and cecum from interstitial fluids and passive shifts in electrolytes such as sodium, chloride and bicarbonate ions. Rapid volatile fatty acid formation especially lactate may represent a subclinical carbohydrate overload state [12] that damages the intestinal tract. In addition the horse must adjust to the induced systemic acidosis, electrolyte imbalance and hypovolemic state.

Short-term colic risk associated with several events were shown to be important in this study. A relatively long time between the event and the colic (median 7 days between event and colic for the horses that had colic after an event) indicates that the pathology involved with colic takes days rather than hours to develop. The longer causal pathway may indicate multiple factors may be involved and multiple timepoints may exist for intervention to prevent colic. Two mechanisms can be proposed for colic following an event: events can interrupt routine feeding and management or change feed and water, indirectly affecting digestion; or alternatively events may initiate a physiological response that precipitates colic. The event could cause pain, excitement, exposure to adverse environmental conditions (hot or cold) or strange situations, exhaustion, or limitations on the horse's movement all which may induce nervous or hormonal transmitters such as catecholamine. Gastrointestinal vasculature and muscles have receptors for these transmitters that would influence gastrointestinal function and motility.

Significant risk factors transport, disease and weather events such as snow both could involve either of the above mechanisms. High frequency of transport was proposed as a risk by Uhlinger[145] and recent transport was a risk in this study involving 14% of the colic cases in this study. Much speculation has occurred concerning weather and colic[128]. Two weather factors, snow and low humidity were shown to be marginally significant colic risks. Snow was only involved with 6 colics, and low humidity was involved with 34% of the colics.

A horse with systemic disease was at very high risk for the development of colic. Colic may be part of the pathological process of some diseases (and not really a risk factor), a sequela to the ongoing disease process or inflammation, or precipitated by the alterations in feeding and management brought about by the disease.

The association of vaccination with colic has not been previously reported. Vaccination was evaluated by both Reeves[132] and Cohen[131] in case control studies and not found to be significant. In this study, this risk was involved with 26% of the colic cases. Risk was not specific for one vaccine type and administration of multiple vaccines did not increase risk over administration of single vaccines. Several biologically plausible mechanisms can be postulated for the association that need to be further explored. Vaccination involves activation of the immune response, an interplay between T-cells, B-cells, and macrophages via immune modulators If receptors for these mediators exist on intestinal smooth muscle or other intestinal cells, there may be additional effects on the gastrointestinal system such as alterations in motility.

In the final combined date-cohort analysis, horses with vices had a marginally significant increased risk. An additional variable related to vaccination history was significant in cohort analysis (PHF vaccination during the study year) and the combined date-cohort analysis (history of encephalomyelitis vaccine) and was unexplained. A connection between vaccination and a colic months later was not biologically plausible. These variables were thought to represent undefined medical management variables. The encephalomyelitis variable was involved with 67% of horses with colic.

Conclusion

In conclusion, a prospective study was an effective method to evaluate risk factors of equine colic using a controlled comparison group. It provided support for some risks factors such as previous colic and the time period 2-5 months after foaling suggested in anecdotal reports and cases series reports and added to our knowledge new risk factors relating to vaccination not previously recognized. The risk factors identified with the greatest potential for intervention are related to the level and type of concentrates fed. These epidemiologic results point the way for further research to determine mechanisms by which colic develops and the development of effective preventive measures.

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CURRICULUM VITAE

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Virginia-Maryland Regional College of Veterinary Medicine
Virginia Polytechnic Institute & State University, Blacksburg, VA
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Doctor of Veterinary Medicine, May 1989
Virginia-Maryland Regional College of Veterinary Medicine
Virginia Polytechnic Institute & State University, Blacksburg, VA

Masters of Science, May 1983
Hood College, Frederick, MD
Program: Biomedical Science
Research Thesis: Rubella IgM and IgG following Rubella Vaccination in Humans and Baboons Measured by Enzyme Linked Immunosorbent Assays (ELISA)

Bachelor of Science, June 1973
University on Minnesota, Minneapolis, MN
Major: Biology

Experience: **Graduate Teaching Assistant**, 1991-1994.
Virginia-Maryland College of Veterinary Medicine
Virginia Polytechnic Institute & State University, Blacksburg, VA
-Assisted with professional DVM courses: Epidemiology and Public Health
-Lectured on statistics, and conducted outbreak investigation laboratories.
-Consulted faculty and graduate students on statistics and survey design for their research.

Special Study, Public Health, 1991 (summer)
Virginia Department of Health, Office of Epidemiology, Richmond, VA
-Conducted a statewide sero-survey at dog shelters to determine prevalence of canine antibody to Lyme disease

Associate Veterinarian, 1989-1990
River Falls Veterinary Hospital, River Falls, WI
- Practiced small animal and dairy medicine

Student Clerkship, 1989 (3 weeks)
Diagnostic Virology Section, National Veterinary Services Lab, Ames, IA
- Studied regulatory and diagnostic functions of this lab

Student Intern, Epidemiology, 1988 (6 weeks)
Infectious Disease, Centers for Disease Control, Atlanta, GA
- Assisted in a field investigation of a human swine influenza death in Wisconsin.
- Assisted in ongoing studies in the viral and rickettsial zoonoses branch.

Lab Technician, Veterinary Immunology, 1986-1988
VA-MD Regional College of Veterinary Medicine, Blacksburg, VA
- Assisted research on immune response to bacterial antigens.
- Performed computer data analysis, mouse immunization studies and immunoassays including Western blot, ELISA and Immunodot.

Research Product Manager III, 1974-1985
Whittaker MA Bioproducts (now BioWhittaker), Walkersville, MD
- Directed product development of immunoassays (ELISA) for antibody to human and animal viruses.
- Supervised 3 technicians
- Performed antigen purification, assay adaptation, comparison studies with other serologic assays, and clinical testing of systems.
- Wrote government product submissions to the USDA and FDA, good manufacturing protocols and package inserts.
- Coordinated transition of product into production and assisted with troubleshooting of existing products.

VISTA Volunteer, Alcoholism Counselor, 1973-1974
Frederick, MD
- Counseled alcoholics and their families in the jail and hospital.

Additional Training: New England Epidemiology Institute, 1991,1993
Tufts University, Boston, MA
6 courses including logistic regression and public health

Honors: Young Investigator Award, Third place-Poster Competition, Fifth Equine Colic Research Symposium, Athens, GA. September 1994.
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Publications:

Tinker, M.K., White, N.A., Lessard, P., Thatcher, C.D., Pelzer, K.D., Davis, B. and Carmel, D. K. Assessment of risk associated events in a prospective study of equine colic. Manuscript in preparation.

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Tinker, M.K., White, N.A., Lessard, P., Thatcher, C.D., Pelzer, K.D., and Davis, B.. Descriptive epidemiology and incidence of colic on horse farms: A prospective study. Fifth Equine Colic Research Symposium, University of Georgia, Athens, GA. September 1994.

Tinker, M.K., White, N.A., Lessard, P., Thatcher, C.D., Pelzer, K.D., and Davis, B. Risk factors for colic on horse farms: A prospective study. Fifth Equine Colic Research Symposium, University of Georgia, Athens, GA. September 1994.

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Tinker, M.K., White, N.A., Lessard, P., Thatcher, C.D., Pelzer, K.D., Davis, B. and Carmel, D.K. Horse, farm and management risk factors for colic on horse farms: A prospective study. International Society for Veterinary Epidemiology and Economics, Nairobi, Kenya, August 1994. Poster presented by Dr. Lessard

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