Yard Differences in Training, Management and Orthopedic Injury In Showjumping, Riding School, and Thoroughbred Race Horses

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Doctoral Thesis
Swedish University of Agricultural Sciences
Uppsala 2012

Acta Universitatis agriculturae Sueciae
2012:27

Cover: Microradiograph from the mid-shaft of the third metacarpus from
a) an exercised horse, b) an unexercised horse.
(photo: McCarthy and Jeffcott 1992, used with permission)

ISSN 1652-6880
ISBN 978-91-576-7663-4

Print: SLU Service/Repro, Uppsala 2012

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Abstract

Musculoskeletal injuries are a major cause of wastage in Thoroughbred racing and equestrian sport. Epidemiological studies in racehorses have demonstrated that risk of injury vary between trainers and with differences in training regimens, but few have studied such between-yard differences in riding horses.

The aim of the thesis was to quantify and compare training regimes, management and measures of injury in racehorses, riding school horses and showjumping horses at herd level, and measure the effect of different training regimens on skeletal adaptation in two-year-old racehorses with bone biomarkers.

Analysing data from an animal insurance database, rates of locomotor problems varied substantially among 136 riding schools. A field study of 19 riding schools with high or low utilization of insurance (HUIO/LUIO) for orthopedic injuries demonstrated differences in management strategies and influence on injury rate and longevity. Experienced managers, highly qualified chief instructors and gradual introduction to riding school work for new horses protected against orthopedic injury.

Showjumping and racehorse training was analysed longitudinally. Ten racehorse trainers in the UK with 194 horses participated. The total number of training days (DAR) was 43,373. Data analysed in the showjumping study were delivered by 31 riders with 263 horses, in four European countries (39,262 DAR). Both showjumping riders and racehorse trainers varied in volume and components of daily training. The mean daily training in the showjumping yards was between 19 and 49 min per DAR. The mean percentages of days lost to training were 23 and 5 in the racehorses and showjumpers respectively. In Thoroughbred racehorses bone biomarker patterns varied between yards, indicating differences in skeletal response.

Conclusions from the thesis support previous results showing orthopedic injury to be a main reason for wastage in horses, and that risk of injury, training regimens and management varies between yards. As analysis of training factors and injury is a new field of study in riding horses, further studies are required to expand the understanding of the multifactorial causes of orthopedic conditions. However, based on results from the thesis and other studies, certain aspects with the potential to influence soundness should be considered by trainers, riders and coaches. This includes a gradual progression of training to allow adaptation to increased loads, training components that improve fitness and prepare for the load required in competition and races, and variation, both of training activities and training load, i.e. periodization.

Keywords: equine, epidemiology, injury, insurance, orthopedic, ridingschool, showjumping, Thoroughbred, training, Warmblood

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Dedication

To my family, close and extended, and B

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Lönnell C, Jackson B, Price J (manuscript). The influence of training on bone cell activity in two-year-old racehorses: a field study.

II Egenvall A, Lönnell C, Roepstorff L (2009). Analysis of morbidity and mortality data in riding school horses, with special regard to locomotor problems. *Preventive Veterinary Medicine* 88, 193-204.

III Lönnell C, Roepstorff L, Egenvall A (2011). Variation in equine management factors between riding schools with previous high versus low insurance utilisation for orthopedic injury – a field study. *The Veterinary Journal* (in press, electronically published), X-Y.

IV Lönnell C, Roepstorff L, Hernlund E, Nostell K, Bröjer J, Weishaupt M, Bitschnau C, Murray R, Tranquille C, van Weeren R, Montavon S., Oomen A, Egenvall A (manuscript) Training strategies in professional showjumping yards

Abbreviations

CH	Switzerland
DMD	Dorsal metacarpal disease (‘sore shins’)
DL	Days lost to training due to injury/disease
DOD	Developmental orthopedic disease
ELISA	Enzyme-linked immunoabsorbant assay
HUIO	High Utilisation of Insurance due to Orthopedic Injury
HYAR	Horse Years At Risk
ICTP	Carboxyterminal cross-linked telopeptide of type 1 Collagen
LUIO	Low Utilisation of Insurance due to Orthopedic Injury
NL	The Netherlands
OC	Osteocalcin
OCD	Osteochondrosis
SE	Sweden
SEK	Swedish Krona
UK	United Kingdom

1 Introduction

1.1 General Introduction and Background

Orthopedic injury is the most important cause of both veterinary costs and wastage of horses (Egenvall *et al*., 2006; Penell *et al*., 2005; Kaneene *et al*., 1997; Clausen *et al.,* 1990). It is also a major cause of wastage in Thoroughbred racehorses (Dyson *et al*., 2008; Verheyen *et al*., 2004; Olivier *et al.,* 1997; Peloso 1994; Lindner and Dingerkus 1993).

Orthopedic injuries have multifactorial causes, both intrinsic (internal) and extrinsic (external) factors, and both modifiable and non-modifiable. The aim to prevent such injuries through assessing modifiable extrinsic risk factors such as training has become a growing field of study in equine veterinary epidemiology. Epidemiology is the science that deals with population medicine to define risk factors for diseases and injuries. In the late 60's and early 70's the equine veterinary community started describing racehorse injury and fatality at population level (Parkin 2008). Farm animal researchers have also developed a population focus, demonstrating significant herd differences in cow and sheep mortality and morbidity (Kaler and Green, 2009; Thomsen *et* al., 2007). Risk factors for mortality and morbidity at herd level has become a major field in production animal epidemiology (Dohoo et al., 2010). Levels that can be analysed, often simultaneously, may include for example litters (for piglets), pens, herds and regional variables. Wastage studies in racehorses first concentrated on risk factors for injuries in races, but more recently included risk factors for injuries in training. These studies have demonstrated that the risk of injury is not equally distributed across the population, but varies at herd level, i.e. with trainer and/or training regimens (Verheyen et al., 2006; Olivier et al., 1997; Moyer and Fisher 1992; Rossdale et al.,1985). Thus epidemiological studies in racehorses have demonstrated the value of comparing herd health status for elucidation of herd-level factors. These methods could also be applied to riding horses, including in equestrian sport.

Horses are extreme athletes and used in a wide variety of disciplines such as racing, dressage, showjumping and pleasure riding. The first known instruction on riding and training of horses was written around 400 BC by Xenophon (Chenevix Trench 1970). The first documentation of horses used for sport is from as early as 638 BC, when both chariot and mounted horse racing were included in the ancient Greek Olympics (Chenevix Trench 1970). Horseracing originated in Central Asia more than 6000 years ago, where nomadic populations raced competitively. By the Middle Ages, English knights brought back horses from the Arabian Peninsula and raced them in Britain. In the middle of the 18th century, horseracing became the first regulated sport in Britain, thanks to the formation of the Jockey Club (britishhorseracing.com). In 2010, UK Thoroughbred racing had 14,340 horses in training with 92,025 race starts and prize money of 99.1 million GBP (british.horseracing.com). Apart from in the UK and other parts of Europe, Thoroughbred horseracing is a major spectator sport in all other five continents.

At the end of the 16th century, riding became regarded as an art, and riding schools were created. The first riding school was established in Naples, Italy by Federico Grisone, teaching dressage riding to royalty and noblemen. The only remaining example of this tradition is the Spanish Riding School in Vienna, Austria. Most classical riding schools later became military academies, which disappeared when the cavalry regiments in most European countries were disbanded. One remnant is the Cadre Noir in Saumur, France. After the Second World War riding for military purposes decreased at the same time as the interest in riding for sport and leisure activity increased. With this as a background, a new kind of school emerged: the commercial riding school (Williams 1975a). In Sweden, the first course for civilian riding instructors was held in 1949 at the Cavalry School, Strömsholm. In 1948 Ridfrämjandet, a Swedish federation to promote riding as a sport for the general public, was created. Today, Sweden has around 500 riding schools with 10,000 horses, and riding is the second largest sport for young people (ridsport.se). Local councils in Sweden have a system of financial support for sports clubs and arenas, including riding schools. Riding schools are run either as non-profit organisations (riding clubs), private businesses, or combinations of these (Smith 2009).

Historically, showjumping is a relatively new equestrian sport originating from foxhunting in the British Isles. Hunting on horseback has been known for millennia in different parts of the world. In the 18th century laws about fencing agricultural land came into force in England. This meant that jumping became an added challenge for riders and horses following hounds (Chevenix Trench 1970). The first record of showjumping is from 1866 in Paris, when a jumping competition was organized at a harness show. After parading in the arena the competitors were sent out into the country to do their jumping, as in the hunting field. It did not take long before fences began to appear in the arena for showjumping competitions. In 1869 jumping competitions were held at Dublin Horse Show in Ireland. International showjumping was organized at Olympia in London in 1907. Showjumping in the modern sense with a course of fences was included in the 1912 Olympics in Stockholm (Williams 1975b).

Causes of orthopedic injuries are highly multifactorial and therefore difficult to assess comprehensively unless looking at large numbers of individuals, and possible risk factors. One generally accepted fact, supported by numerous equine studies, is that training or work regimes has an important influence on the incidence of orthopedic injuries. The usual approach is to work with a well-defined population, in the equine area it could be a specific breed or discipline. Since orthopedic disorders are common across these limits but vary in incidence between disciplines, an interesting approach would be to specifically compare training /working regimes with orthopedic injury outcome across different defined horse populations.

1.2 Epidemiology

1.2.1 Background

The basis for most epidemiological investigations is the assumption that disease does not occur in a random fashion. One of the main objectives is to identify causal relationships between potential risk factors and outcomes such as disease or productivity losses (Pfeiffer 2002), for example wastage in racehorses.

Traditionally discussions on risk factors for equine injury have focused on non-modifiable intrinsic factors, such as conformation. Modern equine studies have demonstrated an association between conformation and length of competition career in Swedish Warmblood horses (Wallin *et al*., 2000) and between conformation and risk of injury in Thoroughbred racehorses (Weller *et al*., 2006; Anderson *et al*., 2004). In recent years studies have shown that the genetic setup of the horse also has an influence on soundness. A study of Standardbred trotters in Norway showed an association between sire and risk of lameness (Gaustad *et al*., 1996). Recent equine studies have demonstrated genetic predispositions for risk of fracture (Price 2009), osteochondrosis (Corbin *et al*., 2011) as well as navicular disease (Diesterbeck *et al*., 2007).

1.2.2 Racehorse injury

In the late 1970's an equine orthopedic research group was formed at the Davis School of Veterinary Medicine in California. The assignment was to work with racetrack veterinarians to determine cause and prevention of specific racehorse injuries. The group pioneered studies on training factors as a component of racecourse fatality. They, and other research groups, have found evidence that a majority of catastrophic racecourse injuries are the result of underlying pathologic conditions, rather than sudden trauma (Stover *et al*., 2008; Udea 1991; Krook and Malin 1988). They also found associations between training factors, the type and properties of racing surfaces and the occurrence of fractures (Estberg *et al*., 1998, 1996, 1995). Also in the 70's Swedish equine veterinarians pioneered research on properties of racing surfaces (Hjerten and Drevemo 1994; Dalin *et al*., 1973).

In 1982, Jeffcott *et al*. presented an analysis of total wastage in Thoroughbred racing in the UK, from failure of conception to mortality. This was followed by a study by Rossdale *et al*. (1985) comparing injury rate in different training yards in Newmarket. This study demonstrated that 39.7 percent of two-year-old horses could not train because of lameness for some period during the season, but with a range between yards from 23.3 to 62.2 percent. This finding highlighted trainer and training elements as potential risk factors for racehorse injury.

Since then, a number of other studies have provided further evidence of trainer, training regimens and surfaces as risk factors for the high incidence of skeletal injuries in Thoroughbreds (Reed *et al*., 2012; Perkins *et al*., 2005; Verheyen *et al*., 2005, 2006 a, b; Parkin *et al*., 2004, 2005; Nunamaker 2000) and Standardbred trotters (Vigre *et al*., 2002).

1.2.3 Other sport horses

These racehorse studies have demonstrated the value of comparing herd health status for elucidation of herd-level risk factors. In contrast, scientific documentation of training regimens or incidence of injury in equestrian sports is rare (Riggs 2010). In Sweden joint disease is the most common diagnosis for veterinary care and death/euthanasia in the general population of insured horses (Egenvall *et al*., 2006; Penell *et al*., 2005). One study in a specialist sport horse clinic showed a significant effect of equestrian discipline on type of injuries (Murray *et al*., 2006). There were significant differences between anatomical site injured and sport category. The study showed that elite eventing and elite showjumping horses had a high proportion of forelimb superficial digital flexor tendon injuries. In addition, elite showjumping horses also had a high proportion of distal deep digital flexor tendon injuries whereas hindlimb suspensory ligament injuries were more common in elite and non-elite dressage horses.

A survival analysis of 3,925 horses in 138 horse operations in Michigan (Kaneene *et al*., 1997) representing a wide range of breeds, showed that there was a decreased risk of lameness in larger stables compared to smaller stables and an increased risk of lameness for active horses (Ross *et al*., 1998). A retrospective study of training, surface use and occurrence of injury in dressage horses found a number of factors that were associated with the occurrence of lameness. This study showed that age, indoor arenas, horse-walkers, back problems, arenas that become deeper in wet conditions and sand-based arenas were factors associated with increased risk of injury. In contrast lunging appeared to have a protective effect (Murray *et al*., 2009; Walters *et al*., 2010).

French researchers have analysed risk factors for osteochondrosis and developmental orthopedic disease in foals and young horses at 21 stud farms in Normandy, in one of the few studies involving non-racehorses at herd level. The study included three breeds, and found a higher risk of osteochondrosis in Warmblood foals versus Thoroughbreds (Lepeule *et al*., 2011, 2009).

1.3 Data collection

Epidemiological studies can be classified into descriptive, analytic-experimental and analytic-observational. Descriptive studies are not designed to evaluate any associations between risk factors (exposure) and outcome. Analytic-observational studies are in turn divided into cross-sectional, case control and cohort studies. Published racehorse studies include case-crossover (Estbergh *et al*., 1998), nested case control (Verheyen *et al*., 2006) and case-control studies (Parkin *et al.,* 2005). Epidemiological studies can also be classified as prospective or retrospective.

In most prospective studies the outcome has not occurred when the study starts. They often provide the opportunity for more detailed information-gathering and attention to recording details of interest than retrospective studies. Retrospective cohort studies imply that the follow-up period has ended when the study subjects are selected. The design of prospective studies will include information-gathering techniques so that all the necessary data are recorded as part of the study itself, or the study could build on available data sources, supplementing data as necessary. Primary data are gathered for the first time by the researcher. Secondary data is taken by the researcher from secondary sources, i.e. one step removed from the actual source population

(Dohoo *et al.,* 2010). This includes central registers such as insurance databases or racehorse registers. Depending on the original source, the database might also include information on the healthy population, which greatly potentiates the use of the database by also enabling estimation of disease frequency in the population (i.e. incidence and prevalence).

Questionnaires used to collect primary data can be qualitative or quantitative. Qualitative questionnaires are also called "explorative" and consist mainly of open questions. Quantitative questionnaires are more often used in veterinary epidemiology. They are designed to capture information about animals, their environment and their management (Dohoo *et al*.,2010). Questionnaires can be administered through personal interviews, by phone or face-to-face, or as mailed or internet-based questionnaires. A diary protocol of for example training is another tool for gathering primary epidemiological data (Jakobsson *et al*., 2010). Gathering data through diary protocols offer challenges of other types than questionnaires administered at a point in time. For example it is important to maintain compliance in recruited individuals and to ensure the same quality of data recording through time.

1.3.1 Equine insurance in Sweden

In Sweden over 75 percent of the horse population is insured (Report of the Commission on Equine Policy, 2000a; 2000b), and the animal insurance company Agria (Agria Insurance, P.O Box 70306, SE-107 23 Stockholm, Sweden, www.agria.se) insures almost one third of the total horse population. This company's database has been used to produce mortality and morbidity statistics in Swedish horses (Egenvall *et al*., 2006; Egenvall *et al.*, 2005, Penell *et al.*, 2005).

Horses could be insured by www.Agria.com for veterinary care as well as for life, and have either complete or limited insurance forms. A complete life insurance policy would reimburse the owner if the horse died, or if it was euthanased as a result of severe injury or illness, as judged by a veterinarian. If the use of the horse was permanently impaired by injury or disease partial compensation could be paid (Egenvall *et al.,* 2006).

1.4 Orthopedic injury and the days lost concept

Several ways to define disease and injury rate of horse population are possible. The incidence rate is the number of new cases in a population per unit of animal time, during a given time period (Dohoo *et al,.,*2010). Incidence rates have been constructed for racehorses by several authors (Reed *et al*., 2012; Dyson *et al*., 2008; Verheyen *et al*., 2004). A further measure of disease and injury is time loss, or days lost from training. The days lost/time loss concept is used as a measure of severity of sports injury in human athletes (Rauh *et al.*, 2005). The days lost concept has also been used to describe patterns of injury and disease, especially in training, in Thoroughbred racehorses (Dyson *et al*., 2008; Rossdale *et al*., 1985; Olivier *et al*.,1997). One important aspect of days lost measures is that usually all health events as judged by the trainer or rider, (in equine studies) or athlete/coach (in human sports studies), are included. Racehorse studies in general include all instances of ill health in calculations of days lost, subdivided into diagnostic groups such as trauma/accidents, respiratory etc (Dyson *et al*., 2008; Olivier *et al*., 1997). However one UK study included only cases diagnosed by imaging, thus excluding for example dorsal metacarpal disease (Ramzan and Palmer 2010).

1.5 Biomechanics and bone biomarkers

1.5.1 Adaptation to training

Physical conditioning is a key principle of injury prevention. Biological systems can adapt to loads that are higher than the demands of normal daily activity. Training is essential for horses to compete effectively and safely. It prepares the equine athlete or leisure horse by inducing the physiological adaptations necessary to perform with minimal risk of injury. Training is task-specific, i.e. the task for which conditioning is desired must be performed (Hinchcliffe and Geor 2008).

There are three components that can be manipulated in training; frequency, duration and intensity, which in combination describes volume. Training loads must be increased gradually to allow the body to adapt and to avoid injury (system failure due to overloading). Loading must also continue to increase incrementally as adaptation occurs, otherwise the training effect will plateau and further improvement will not occur. While training is task-specific, the training program must consist of a variety of elements, including cardiorespiratory (aerobic) fitness, general strength, anaerobic fitness (power), speed, neuro-muscular skills development, flexibility, and mental preparation. Each athlete, or horse, will respond differently to the same training stimulus. The concept of periodization, i.e. varying the type, volume and intensity of the training load, allows the body an opportunity to recover, and to adapt. (www.IAAF.org).

Different tissues in the body vary in their rate of adaptation to exercise, both in humans and horses. While the time required for adaptation of muscle metabolism and cardiac fitness is weeks or months, connective tissue such as bone, cartilage, tendon and ligaments take months to years to adapt, both in humans (Kjaer *et al*., 2003) and horses (Clayton 1991).

1.5.2 Adaptation of bone

The high incidence of fractures in racehorses has led to research focusing on skeletal response to exercise, and fracture resistance. Research in biomechanics has tested the effect of training on bone and cartilage in Thoroughbreds, with the eventual aim to prevent musculoskeletal injury. Equine treadmill studies have shown that equine bone adapts to the increased loads of exercise (Frisbie *et al*., 2010; Jackson *et a*l., 2003; Kawcak *et al*., 2000; Riggs *et al*., 1999; Price *et al*., 1995; McCarthy and Jeffcott, 1992). For example, McCarthy and Jeffcott (1992) found that bone density increased significantly in two-year -old horses after performing a high speed treadmill training program, compared to controls that only had done walking exercise.

Human and experimental animal studies in this field are primarily concerned with properties of bone in response to exercise, often related to prevention of osteoporotic fracture. Studies in humans (Ward *et al*., 2005; Bass *et al*., 1998; Fehling *et al*., 1995) have also shown differences in skeletal response to exercise depending on the type of exercise performed. The skeleton is responsive to physical activity, particularly during growth and adolescence, with weight bearing activity resulting in increased bone mass. Increased bone mass in turn has been shown to protect against fracture. Human athletes whose exercise includes exposure to strains of high magnitude, high strain rates, or both (weight lifters and squash players) have high bone mineral density. This is in sharp contrast to athletes whose exercise is non-weight-bearing (cyclists and swimmers), and of people described as just "physically active" whose bone mineral density does not differ from that of sedentary controls (Heinonen *et al*., 1995, 1993; Fehling *et al*., 1995).

Studies in young horses have also demonstrated the response of bone and cartilage to exercise during growth, in view of future potential for soundness. While sporthorses have previously not been a subject of training studies, a major experimental study analysed the musculoskeletal response to confinement versus intense exercise and pasture time in Dutch Warmblood foals and yearlings (Barneveld and van Weeren 1999; Cornelissen *et al*., 1999). The study for example found that, the collagen-related components of articular cartilage were not compensated in foals confined to a stable for the first five months of life and then exposed to exercise, in comparison to foals that were raised on pasture (Brama *et al*., 2002).

Adaptation to loading can be initiated by short periods of cyclical loading, such as jumping or short bursts of running. Strain has been shown to increase with increased speed during running or racing. Evidence thus suggests that the osteogenic response is greater when exercise involves high strain rates and high strain magnitudes. As a result it has been suggested that exercise intensity may be more important than duration in bringing about adaptive responses (Lanyon 1996).

There is evidence that some loading regimens may have negative effects on bone. Human studies have observed reduced bone mineral density and bone mass, and increased bone turnover in long distance runners (Hetland *et al*., 1993).

In equine studies under field conditions Boston and Nunamaker (2000) have shown that training for long distances at slower speeds is associated with an increased risk of fatigue injury of the third metacarpal bone ('bucked shins') in two-year-old Thoroughbred horses in the US. Verheyen *et al*. (2006) similarly found in the UK that in previously untrained bones, accumulation of canter exercise increased the risk of fracture in racehorses.

The balance of adaptation required to withstand higher loads required in for example racing, versus pathological changes, is complicated. Some joint injuries and fractures in racehorses are located in areas that sustain repetitive impact loads in high intensity exercise. An analysis of the third carpal bone from horses in the Bristol University treadmill project showed that the increase in trabecular thickening and density in the bone in response to exercise, was localized to those regions underlying common sites of cartilage degradation. The interface of the thickened trabeculae with the normal architecture co-incided with a common site of clinical fractures in the third carpal bone (Firth *et al*., 1999). Similar findings have been reported for the distal surface of the radial carpal bone, the proximal aspect of the first phalanx, and the medial and lateral condyles of the metacarpal and metatarsal bone (Riggs and Boyde 1999).

1.5.3 Surfaces and injury

Epidemiological studies of racecourse injury have identified surface properties and types of surface as a risk factor for orthopedic injuries and racecourse mortality (Parkin *et al*., 2005; Williams *et al*., 2001). Biomechanical studies have shown that the distance trained as well as the training surface influence the skeletal effects of training and the injury rates (Nunamaker 2000; Moyer and Fisher 1992; Young *et al*., 1991).

1.5.4 Bone markers and training

It is unclear whether results of the effects of training in experimental treadmill studies can be directly transferred to conditions in commercial racehorse training. A major limiting factor for analyzing the effect of training on the skeleton of racehorses in field studies has been lack of non-invasive methods available for accurately measuring bone mass in the standing, conscious, horse. Imaging methods requiring anaesthesia or tranquilizers, are not feasible in commercial racing yards. However, a number of studies have shown that bone biomarkers, which are matrix components or enzymes released into the circulation during bone modelling and remodelling, may be useful in monitoring changes that occur in response to exercise in horses. An experimental study in two-year-old treadmill trained Thoroughbreds found that decreased bone marker concentrations were associated with higher bone density and bone mineral content in horses doing high speed exercise, versus sedentary controls (Jackson *et al*., 2003). Other studies have used bone biomarkers to monitor the effects of exercise and training in Quarter Horses (Hiney *et al*., 2000; Nielsen *et al*., 1998), Standardbreds (Vervuert *et al*., 2002) and Thoroughbreds (Inoue *et al*., 2008; Carstanjen *et al*., 2005; Price *et al*., 1995), under experimental conditions and during normal training.

In summary, racehorse studies have demonstrated differences in injury risk and musculoskeletal adaptation with different training regimens. Previous studies in racehorses, other animals and of human athletes have also demonstrated that the musculoskeletal system needs longer time to adapt to exercise than the respiratory or cardiovascular system. This adaptation thus must be gradual, and also targeted to the work expected in different disciplines. It can be assumed that differences in injury rate between yards are associated with differences in training strategies and how appropriate they are for the type of work expected. The equine industry lack scientific insights on training risk factors for injury in riding horses, as demonstrated in racehorse studies.

2 Aims of the thesis

The aims of this thesis were to study yard differences in training regimens, management and risk of equine orthopedic wastage in horses used for sport and leisure. In addition to this, the skeletal adaptation to training, measured by bone biomarkers in young racehorses was studied. Another overall goal was to contrast training loads and injury patterns in the various horse populations studied.

2.1 Specific aims of the thesis

Paper I

The aims were a) to characterise and compare training regimens for two-year-old Thoroughbred horses in commercial training in terms of speed and cumulative distance trained over the season, b) to determine if the concentrations of two biomarkers of bone cell activity changed between the start and end of the training season, c) to determine differences in biomarker concentrations between trainers and d) to determine the effects of different intensities of training (slow canter, canter, fast work) on bone biomarkers.

Paper II

The aim of the study was to determine the incidence and mortality of disease, and survival rates, in riding school horses, as well as the variation in incidence and mortality between different riding schools. The study was based on utilisation of insurance, both general and with special focus on locomotor problems.

Paper III
The aim of the study was to describe and compare management factors in riding schools with High versus Low Insurance Utilisation due to Orthopedic Injury (HIUO/LIUO), as an indirect measure of wastage.

Paper IV
The aim of this study was to quantify and compare training in showjumping yards at professional level, in relation to time trained, type of activity and intensity.

3 Material and Methods

3.1 Study designs and study periods

Study I and IV were prospective cohort studies. Study I followed Thoroughbred yearlings in ten UK training yards from entering training in November/December 1998 until the end of their two-year-old racing season in September 1999. Study IV followed Warmblood showjumping horses for six months per year, during the outdoor riding season. The study involved riders in Switzerland (CH), Netherlands (NL), Sweden (SE) and the United Kingdom (UK). In SE start dates were mid-April in 2009 and May 1st in 2010 (for second season participants). In CH riders started in a staggered manner from May 1st 2009 and in NL from June 2009. In the UK, riders started from August 2009. Both studies were designed to quantify and analyse training and health data at herd and individual level. In addition, serum samples were collected from participating horses for analysis of bone biomarkers in study I. In paper II, data from an equine insurance database (1997-2002) were used to compare incidence of disease, mortality and survival of horses between different Swedish riding schools. The study focused on locomotor problems. Paper III was a retrospective field study. Based on the results from study II, riding schools with high respectively low rates of insurance utilisation for orthopedic injury were visited in spring 2006. Senior staff in each riding school were interviewed based on an extensive questionnaire.

3.2 Study populations

3.2.1 Trainers and racehorses (I)

The recruited ten Thoroughbred racehorse trainers were based in different regions of the UK. Selection was based on recommendations made by the trainers' veterinary surgeons. The main criteria was trainers' potential to comply with the study design. In total the trainers initially nominated 194 Thoroughbred yearlings for the study.

3.2.2 Showjumping riders and horses (IV)

The participating showjumping riders were selected from the National Equestrian Federations' rider rankings for 2008. Rankings are based on competition results. The inclusion criteria were; having a minimum of five horses in training, started at Advanced (i.e. S-level) in 2008, and/or ridden at a professional level. Riders based in dealing yards were excluded, due to expected high turnover of horses, with the exception of the NL. In Sweden, riders who had repeated competition trips abroad were excluded, as they were expected to have difficulties in maintaining consistent training records for individual horses while travelling. Riders were asked to select horses that were 4 years of age or older and were expected to stay in the yard for the main part of the study period. According to the rider's preference all horses in the yard were included, or a subset of horses.

3.2.3 Riding schools and riding school horses (II and III)

Data for paper II and III were extracted from the Agria insurance company's computerized database, for the years 1997-2002 (Egenvall *et al*., 2006). The database had no classification of clients. Riding schools were instead identified by searching the official telephone diary (www.eniro.se) for riding schools ("ridskola"), and matching with the database. In March 2005, the term riding school produced 346 establishments and the synonym "ridhus" 123. Some were found in both searches. Riding schools specializing in hacking/trekking or with less than 20 horses with complete insurance during 1997-2002 were excluded, yielding a total of 136 riding schools for analysis. All horses with complete insurance for both life and veterinary care were identified. The dataset in paper III was a sub-selection of riding schools from paper II. Riding schools with an average of at least eight horses insured for both veterinary care and life insurance annually from 1997 to 2002 were included (Egenvall *et al*., 2009). To select 10 HIUO and 10 LIUO riding schools, one ranking was made for veterinary care claims and one ranking for life insurance claims. The five riding schools with the highest average annual incidence rate for life and the five riding schools with the highest average annual incidence rate for veterinary care were identified. As three riding schools were in the top five group for both mortality and morbidity this produced seven riding schools. In addition three riding schools were selected alternately from the veterinary care and mortality rankings below those already selected, to reach n=10. The same procedure was repeated to select the LUIO group, with the least claims for veterinary care and mortality.

3.3 Questionnaires and protocols

Trainers (paper I) and riders (paper IV) registered daily training data on standardized forms. At the start of study the trainer's assistant or head girl/lad (paper I) and rider (paper IV) were interviewed for background information regarding the facilities, horses trained on the premises and background on training regimens. This included fitness regimens with estimated speeds. Horse data included age and gender in all three studies, plus sire (paper I), breed/studbook (paper III and IV) and time in yard (paper III and IV). In all three studies training gallops (paper I), indoor and outdoor riding arenas (papers III and IV) were visited at least once, together with the trainer or his assistant, riding school manager/instructor or rider.

The training protocols in study I were designed to register daily horse level information on distance trained, training surface and at what speed i.e. intensity; hack canter (> 18 s/furlong (1 furlong=200 m), canter (14 to 18 s/furlong) 'work' (< 14 s/furlong), or if the horse participated in a race. Distance and speeds for race days were obtained from the Racing Post website (www.racingpost.co.uk). The daily data further included other activities such as long reining or walking in an automatic horse walker. In study IV the protocols were designed to register the duration, intensity and type of exercise; jumping, hacking, flat work (e.g. dressage), fitness work and competition. In addition to this, riders registered non-ridden training i.e. turnout (pasture or field), walking by hand or in a mechanical walker, long reining and lunging. Competition data were registered as class/es competed. Intensity of training was based on the individual rider's perception, marked on a Visual Analogue Scale (VAS). In both study I and IV health notes were also registered as part of the training protocol, as part of the study design. If horses were not trained due to medical or orthopedic reasons riders and training yards registered type of condition. Riders also described if any examination was done by a veterinarian, farrier or chiropractor. In Sweden veterinary cases were validated by telephone calls with the treating veterinarian. In the racehorse study fractures, which was a study focus, were validated by radiological examination or scintigraphy.

In paper III participating riding schools were visited, facilities viewed and a senior staff member (manager, chief instructor or administrative head) interviewed, based on a substantial questionnaire including data on horses, management, feeding, work load, students etc. The interview questionnaire was based on consultations with specialists in the riding school industry, who identified anecdotal risks and protective factors relative to wastage. The questionnaire was tested and modified through telephone interviews with five other riding schools before the start of the field study.

3.4 Bone biomarkers and laboratory analysis (I)

The bone biomarkers measured in paper I were osteocalcin, for bone formation, and the carboxy-terminal telopeptide of type I collagen (ICTP) for bone resorption. The concentration of osteocalcin was measured in serum samples using a competitive immunoassay (MicroView Osteocalcin, Quidel Corporation, US) that has previously been validated in horses (Hoyt and Siciliano 1999). As osteocalcin concentrations are higher in horses than humans, all samples were diluted 1:2 with the assay wash buffer, in order to ensure that the levels measured fell within the range of the assay (0 to 32ng/ml). The limit of detection of the assay was 0.45ng/ml. Samples were run in duplicate and showed that the intra-assay coefficient of variation for osteocalcin was 7.2 percent. The inter-assay variation was 9.3 percent. The concentration of ICTP was measured in serum using with a commercially available radio-immuno-assay (RIA) (Orion Diagnostica, Finland) previously validated for use in horses (Price *et al*., 1995). The limit of detection of the assay was 0.5µg/L. The intra-assay coefficient of variation was 4.3 percent and the inter-assay variation was 5.7 percent.

3.5 Data processing and statistical methods (I, II ,III, IV)

For paper I, III and IV all data from training sheets and the questionnaire were manually entered into Excel databases (Microsoft, Redmond, WA). For study II data were extracted from the insurance company's computerized database and details on data management have been presented previously (Egenvall *et al*., 2006, 2005). Statistical analyses in paper I, III and IV were done using SAS software (SAS Institute Inc. Cary, NC). In paper I SPSS (IBM Corporation, Armonk, NY) was used for univariate and non-parametric analysis. In paper II STATA 9.1 (Stata Corporation, College Station, TX) was used for multivariable analysis.

Riders' protocol reports on veterinary data, were used to calculate days lost to training (DL) in paper IV. Processing of veterinary data in the racehorse study has been described previously (Jackson *et al.,* 2005ab). Days of reduced training for sound horses were determined from the training protocols, veterinary notes and through consultations with the trainer assistant or head lad, and recorded as "easy days", the equivalent of rest days in paper IV.

In study I DL for all conditions were also registered, and defined as when a horse did not train at a hack canter speed or faster, for veterinary reasons.-This included box rest, led by hand, and walking or trotting exercise. DL was recorded based on veterinary data primarily focused on fractures and sore shins, presented elsewhere (Jackson *et al*., 2005ab). No or light exercise for managemental reasons were classified as 'easy days'. In paper IV DL were defined as days when horses were not trained due to health reasons, including light work due to disease/injury (including early signs). The definition of not trained or light work was paddock or field rest, led by hand, mechanical walker, lunging, or hacking/flatwork at walk/trot and of short duration. DL were deducted from the total days with data to calculate days at risk for training. Rest days were when healthy horses did not train, or were in light work, as defined for DL. Weekly rest days was one example in this category.

In paper I differences between training yards in total overall distance trained, and in total distance trained at each of the three individual training speeds, were analysed using analysis of variance with a post hoc Scheffe test. In paper I only exercise at hack canter and higher intensities, on training gallops, was analysed. Differences between bone biomarkers concentrations at baseline and at the end of the study (across all horses and within each training yard) were analysed using a paired t test.

The effect of different training components on bone biomarkers was analysed by looking at the relationship between bone biomarker concentrations at the end of the study and the cumulative distance trained for each speed category over the season. The effect of three categories of training speed and of age, gender and season on biomarker concentrations was studied by including these as main and first order interaction effects in the model, with osteocalcin and ICTP as outcome variables. In this analysis training yard was included as a random effect. Statistical significance was assessed using a P-value of 0.05. Different models were compared using Akaike's Information Criterion. For the second analysis, Spearmans Rank correlation was used to establish the relationship between biomarker concentrations at the end of the study and total distance trained at hack canter, canter and total distance trained at 'work' respectively.

For paper II descriptive statistics were calculated overall, by gender, breed group, geography, certification and life-insurance value. The distribution of the costs for veterinary care (total costs on the receipts) was determined and a ratio was constructed taking the sum of the costs (divided by 1000) and further dividing by the averaged yearly horse-years at risk (HYAR). The distribution of this ratio was also evaluated by riding school and costs for veterinary care were also evaluated by year. Incidence rate calculations were used with the time at risk (insured time during study period) as the denominator. For comparison to earlier papers, results from the whole database incidences were based on yearly calculations with the same case-definition as previously. For the sake of clarity, these yearly incidences, and their standard errors, were averaged over the 6 years, stated as averaged rates (a procedure taken for descriptive statistics as well in paper II). Incidence rates are presented overall, by gender, breed group, age group, geography, certification, life-insurance value, diagnostic category and year and/or combinations of these variables.

The survival to first veterinary-care claim and to a submitted life claim for locomotor problems was determined after stratifying on age group, using the Kaplan–Meier method. The population in the survival calculation was all horses first insured within the study period. Survival estimates were stratified by age at entry. The survival curves, within insurance type, were compared using the log-rank test using pairwise comparisons. Cox regression was used for multivariable analysis with the outcome locomotor problems, using two datasets in three models. Only horses insured within the study period and where age at entry was >_4 years were included. For the outcome time to first veterinary-care event for locomotor problems all these horses were used (dataset I used for model I). For the outcome defined as a locomotor life-insurance event both dataset I and dataset II were used. Dataset II was the population of horses with reimbursed veterinary-care events in dataset I, from which model III was developed (outcome life claim and the time variable was the time between veterinary-care and life events). Only riding schools with >1 horse in the dataset were included (omitting 1 observation in dataset I and 23 in dataset II). The variables tested for inclusion were breed group, gender, age at entry, geographic location, facility and instructor certification and life-insurance value. The baseline hazard was specified as age-specific. Time at entry was age in years at age at entry and time at exit was age in years at exit. Riding schools were included as frailties (~random effects in survival analysis). The likelihood-ratio test of theta for the frailty effect was used to assess the riding school effect statistically. A P-value of 0.05 was considered statistically significant. Two-way interactions, except those with terms involving insurance value or geography, between variables that remained in reduced models were investigated.

In paper III continuous riding-school level variables for the two utilisation-groups were compared using the Wilcoxon's signed rank sum test and categorical variables using Fisher's exact test. Because of the exploratory nature of the study and the limited power, borderline associations were discussed for $P < 0.10$. Demographic parameters were also explored using individual level data and evaluated by the Chi-square test for categorical variables. These were further evaluated in logistic regressions with riding school as random effect to account for clustering.

For the showjumping study (paper IV) mixed models were created. The weeks were used as repeated effects, with horse within yard as subject effect and with a compound covariance structure. The fixed effect variables tried in paper IV were: gender, age, whether the horse had a history of orthopedic problems the previous season, mean class from the season, year (2009/2010), month, country and whether the horse had days lost during the study period. The outcomes were mean daily total time trained and mean daily flatwork, as the main component of training. Fixed effects were reduced from full main effects models to those that contained only significant effects (all containing the random effect). Two-way interactions of variables left in the primary main effects model were tried, ignoring those with month. The P-value limit in all steps was 0.05. The variation from the riders was assessed using the compound symmetry covariance parameter estimate and dividing it by the sum of this estimate and the residual variance.

4 Main Results

4.1 Response rates

Ten racehorse trainers were recruited for a prospective ten month study in paper I, and all completed. The total days at risk (DAR) were 43,373. Data analysed in the prospective showjumping study in paper IV were delivered by 31 riders, out of 61 originally recruited for the study. The total DAR were 39,262. Some study riders had stable jockeys or partners engaged in training and/or competition, but with the study rider having main charge. Six study riders in Sweden shared yards, giving a total number of training yards of 28 in the study. In total 263 horses were included, all European Warmbloods.

In the retrospective paper II data on 5,140 horses 4 to 22 years old were included. For veterinary care the average yearly number of HYAR for riding school horses was 2,299. For mortality the yearly average overall figure was 2,458 HYAR. In paper III one riding school, of the 20 selected, declined to participate, i.e. 95 percent agreed (no reserve was listed). The total number of horses in study III was 307.

4.2 Yard differences in management and rest (I, III, IV)

A majority of racehorse trainers used mechanical walkers for non-ridden exercise. Only one trainer’s horses had regular turnout in a field. All yards had one rest day per week. In study III all riding schools in both groups had daily turnout in paddocks or fields. In LUIO schools the mean time outside was 4.1 h, compared to 4.5 h in the HUIO group (P = 0.60). Riding schools in the LUIO group tended to have longer periods of summer pasture rest, with a mean of 5 weeks (range 0-7.5) versus 3.7 weeks (range 2-4) in the HUIO group (P = 0.10). All riding schools had a minimum of one rest day per week.

In study IV volume and frequency of non-ridden exercise, such as turnout, varied between riders. All showjumping riders, except one, used regular turnout. Calculated as a total mean (± standard deviation), horses had 3.8 ± 4.5 h daily in a paddock or field, with substantial variation among and within countries. All riders except three used mechanical walkers as part of the horses daily exercise regime. All but five riders walked horses by hand, as light exercise or for relaxation, mainly at competitions. With ridden and non-ridden exercise combined, the total mean daily time outside the stable for the showjumping horses varied from 1.3 h to 11.3 h. The mean proportion of rest days (excluding injury or ill health) was 23 percent (range 10 percent - 38 percent).

4.3 Yard differences in training and workload (I, III, IV)

Training regimens varied for two-year-old racehorses and showjumping horses in paper I and IV, both in volume and exercise activities. For the racehorses the main training components were canter/gallop at different intensities, or speeds, derived from the trainer's own records. 'Hack Canter' (> 18 s/furlong (200 m) and 'canter' (14 to 18 s/furlong) in various combinations constituted the daily training. 'Work' (< 14 s/furlong), i.e. at or close to, racecourse speeds) was added 1-2 times a week when the horse was in full training. The cumulative mean total training in furlongs per yard ranged from 922 to 2,228 over the season (figure 1). The proportion of the speeds in the total distance trained varied. 'Hack canter' ranged between trainers from 6.3 percent to 85.8 percent of total furlongs trained, 'canter' from 10.7 percent to 87 percent, and 'work' between 1.8 percent and 33.9 percent. Eight of the trainers used 'canter' as their main component of training during the season, but with a range of cumulative mean total furlongs from 456 in yard 10 to 1,709 in yard 7. In six yards, horses did a mean of < 1,000 'canter' furlongs cumulatively. Two yards (3 and 8) had 'hack canter' as the main training component, at 1130 versus 1150 total furlongs. In another example of differences in total strategies that represented 85.8 percent of total training in yard 3 but 59.7 percent in yard 8. Horses in all other yards did 58-612 cumulative furlongs of 'hack canter'. For two yards (2 and 5) 'work' (< 14 s/furlong) ranked second to canter in the proportion of training speeds. Nine of ten yards did a cumulative total of less than 200 furlongs 'work' during the season, versus 450 in yard 10.

Hack canter was a significant training component between December and February, when horses were in early stages of two-year-old training. 'Work' was generally introduced in April with one exception (yard 3) where canter was not introduced until May and ‘work’ not introduced until June. In contrast, all other yards had introduced canter by February (data not shown).

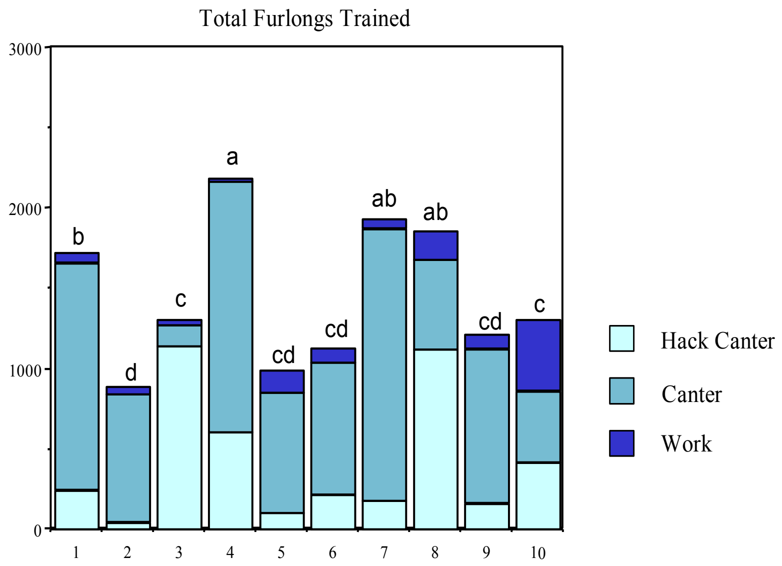

Figure 1. Cumulative training of two-year-old racehorses during a ten month season. Calculations are based on horses that trained > 80 percent of training days. The figures shows the total number of furlongs that a horse in full training would do on average over the course of the season, based on means for each training yard (1-10). Total furlongs have been subdivided to show the different contributions of each type of training speeds. Those yards without a common letter are significantly different from each other.

In paper IV the workload for showjumping horses varied substantially by rider, based on volume and frequency of hacking, flatwork, lunging, fitness, jumping and competition. Ridden training (mainly flatwork) was the major part of the total time trained. Riders varied in total time trained from 19-49 min per DAR. While all riders had flatwork and jumping as part of their training regime, the frequency for flatwork varied between riders (1.4 to 4.8 sessions per week) (figure 2). For all ridden training the range of sessions per week was

4.6-6.2 sessions/week (paper IV Appendix 3). Rider variation could be exemplified by the range of outdoor hacking from < 5 percent to 47 percent of the time trained. All riders, except four riders in the UK, used lunging as part of their training (with most horses.) Five Swedish riders also used hillwork as part for fitness training. Additional activities included loose jumping and loose canter, treadmill work and longreining. Each of these latter activities were used by 1-2 riders each.

Figure 2. Descriptive horse-level data for training, in showjumping study yards in The Netherlands, Sweden, Switzerland and the UK. Mean are shown for weekly mean numbers of sessions in the training categories: hacking, flatwork, lunging, fitness, jumping and competition.The total mean representents volume of training, based on means for all healthy days available, Sessions per week are based on horse means.

In the total time trained model riders contributed 49% of the variation and 20% in the flatwork model. The significant variables in the model with the outcome total time trained were: proportion DL, month, country and mean class competed, plus an interaction between mean class competed and the proportion DL. The variables in the flatwork model were: proportion DL, month, country, year and an interaction (proportion DL and year). Hence the proportion DL was significant and involved in interactions in both models.

The mean perceived intensity of training was for outdoor hacking 26 percent (± 16), flatwork 52 percent (± 14), jumping 63 percent (± 11) and for fitness work 63 percent (± 13). Based on the riders estimation, the fitness canter speeds varied between 350 to 800 m/min. In SE 5 riders did fitness canter at < 400 m/min. Four of the Swedish riders performed fitness canter on a racetrack (> 700 m/ min).

In paper III, the weekly workload for horses varied from 450 to 1080 min among individual riding schools. The weekly mean was dependent on the number of lessons as well as the duration of these (45-60 min). However , the means in the two insurance groups (LUIO/HIUO) was similar at 738 versus 764 min, and the difference not significant. The number of lessons per day were similar (two or three lessons per day) between groups (LUIO/HIUO). The mean planned hours of lessons per week were also similar between groups, at 15.6 h in the HUIO group compared to 14.1 h in the LIUO group.

Significantly more of the LUIO riding schools had more than 11 weeks introduction time for newly recruited horses (> 6 years age), compared to in the HUIO group. The introduction time for new recruits varied from 0 to 55 weeks between riding schools. When introduction was used, strategies included a gradual increase in lessons on weekly basis.

4.4 Professional experience of participants

In general, riding schools with a low utilization of insurance due to orthopedic injury had more experienced and better qualified chief managers and chief instructors compared to the riding schools with a high utilization of insurance. The mean professional riding school experience for managers of LUIO schools was 18.5 years compared to 10 years for managers of HUIO riding schools, (P = 0.09). A significantly higher proportion of the LUIO riding schools had managers with at least 11 years' work experience (at the same or similar positions) (P = 0.02). In the LUIO group, 70 percent (n = 7) of schools had chief instructors with a Level 3 instructor's exam and/or competition experience at S (Advanced) level, compared to 11 percent (n = 1) in the HUIO group (P = 0.02). Level 1–3 is an internationally acknowledged grading of riding instructor qualifications (3, highest; 1, lowest).

In addition there was a significant difference in type of business management between the two groups. All riding schools in the HUIO group were under riding club/local council management, compared to 40 percent in the LUIO group (P = 0.03). The remainder of the LUIO group was under private management.

4.5 Bone metabolism in response to training

The pattern how bone biomarker changed in response to training varied between racehorse training yards. Overall there was a decrease in bone biomarker concentrations between the start and the end of the two-year-old training season, but with a variation between yards. When individual training components were analysed ‘work’, i.e. gallops at or close to racecourse speeds, was found to be significantly associated with decreased osteocalcin (P = 0.027) and ICTP concentrations (P = 0.001). At the end of the training season there was an inverse correlation between cumulative distances trained at ‘work’ and osteocalcin (P = 0.001) and ICTP levels (P < 0.0001). However, training for longer distances at canter was associated with an increase in ICTP levels (P = 0.008).

4.6 Yard differences in incidence of injury and days lost

In paper IV the proportion of days lost to training was generally low compared to for racehorses in paper I, with a mean of 5 percent. Of 263 horses 127 had days lost due to health reasons during the study. By rider the fraction of days lost varied from 21 percent, to around 1 percent for several riders. The mean percentage of DL for the whole group of riders was 6 percent. The main

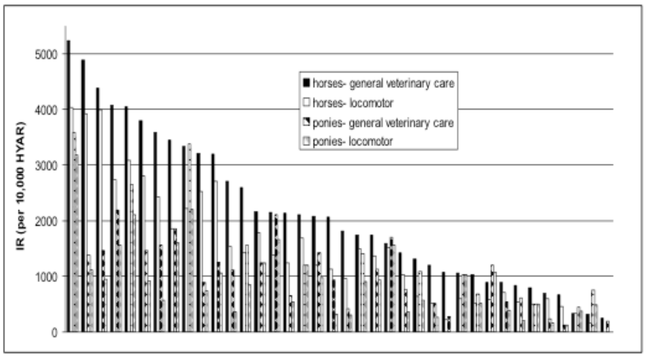

Figure 3. Incidence rate of insurance utilization of locomotor problems and general veterinary care in riding schools in study II, showing both ponies and horses (> 148 cm).

reasons for DL was non-acute orthopedic injury including backs (56 percent of DL), acute orthopedic, mainly accidents and trauma (22 percent), medical (12 percent) hoof problems (7 percent) and undefined (4 percent).

In study I separate analysis showed a significant difference (P= 0.001) between yards in the percentage of days lost and incidence of fracture and dorsal metacarpal disease. The overall fracture incidence in two-year-old racehorses was 1.38/100 horse months in training, but with significant differences between yards. The percentage of days lost varied from 9.2 to 32.6 between the ten yards, with an overall mean of 22,9 percent. Descriptively the yard with the highest rate of days lost also had the highest percentage due to orthopedic conditions, at 28.6 percent. Days lost to non-orthopedic conditions also varied, from 9.5 percent to 0.005 percent. The main reason for days lost other than musculoskeletal conditions was respiratory disease. In December-January, 1-2 months after entering training, horses in a majority of the yards suffered from respiratory infections.

Paper II demonstrated that rates of total veterinary claims and locomotor problems varied substantially between the included riding schools (figure 3). In total 2,000 horses (39 percent of all the 5,140 included riding school horses) had veterinary-care or life claims during the study period. Of the 2,000 horses with claims, 1,628 horses (81 percent) were settled for veterinary care at least once during the study period while 1,122 (56 percent) had life claims submitted (one horse could have both a veterinary care and life claim). Approximately 1 percent of the horses (n = 53) died but were not claimed, and 64 percent were reimbursed for loss of use i.e., contributed to mortality rates.

5 Discussion

5.1 Yard differences in training and management

The papers in this thesis support previous findings demonstrating that orthopedic injury is the major cause of morbidity for all three horse categories included. Results in this thesis also reflect a marked variation in the incidence of orthopedic injuries and lost training time between the different study populations as well as between different yards. These results are in accordance with findings from previous studies showing differences in risk of injury between different yards and different training regimens (Verheyen *et al*., 2006a; Nunamaker 2000).

The three main component of training are frequency, duration and intensity. In general, training effects can be manipulated by changing the proportion of any of these components. However, the balance of adaptation with intensity to withstand higher loads required in for example racing, versus overload causing pathological changes, is complicated in all training, not least in racehorses. Experimental studies with ex-vivo material have demonstrated that some joint injuries and fractures in racehorses are located in carpal and metacarpal joint areas that sustain repetitive impact loads in high intensity exercise (Riggs and Boyde 1999). Studies in racehorses have demonstrated a need to balance volume with intensity. One example of the sensitive balance of loads is from findings by Nunamaker (2000) and Verheyen *et al*. (2006a) of a negative effect of regimens with large volumes of slower speed work at hack canter and canter, in addition to high intensity work. This could be one explanation of conflicting results in studies on racecourses in California presenting an accumulation of high-speed work as a risk factor for (catastrophic) racecourse fractures (Estberg *et al*., 1996, 1998). In these studies however only timed racecourse training was analysed, without quantifying the total volume of training.

Results from the thesis demonstrate differences in patterns of injury between disciplines. For example the Thoroughbred racehorse trainers had a mean of 22.6 percent days lost to training versus 5 percent for the showjumping riders, i.e. substantially lower. Different equine disciplines potentially could adapt training components from other fields. This for example includes improving fitness by canter or hillwork, as used by many showjumping riders in the study. The finding that fitness training had different designs depending on yard was one observation in the showjumping study.

5.1.1 Intensity

Human and animal studies have demonstrated that to have a training effect, the load has to be above a certain threshold, or intensity. The load required in races or competitions should be prepared for in training. Once a sufficient signal of high load has been achieved, numerous repetitions do not improve the training effect. Racehorses compete at or close to racecourse gallop speed < 14 s/furlong. Trainers varied in the extent racecourse speed, or 'work' was included in regimens. Fast work, i.e. exercise causing high bone strain, was found to reduce turnover of osteocalcin and ICTP in paper I. This suggests that high strain/high intensity exercise has an effect on bone metabolism reflecting adaptation. These findings are supported by studies in Thoroughbreds showing that high speed (i.e. intensity) training had a protective effect on the occurrence of fractures and dorsal metacarpal disease ('sore shins') (Verheyen *et al*., 2006a; Parkin *et al.,* 2005; Nunamaker 2000). Results from Nunamaker (2000) and Verheyen *et al.* (2006) point out the importance of introducing more intense variables in a regime gradually.

In elite dressage horses the addition of 350 m/min (aerobic) fitness canter to training regimens produced reduced (more appropriate) body weight, improved vitality and improved grades and placings in a Grand Prix level competition lasting several days, reflecting improved aerobic fitness (Nolting 2010).

Showjumping horses had medium intensity work compared to the other two groups, but with wide variation between yards. This included whether fitness canters and hillwork was included, and type and level of showjumping training. Some horses participated at international level up to Grand Prix (data not shown). The work required by riding school horses in contrast was of low intensity, with mainly novice dressage lessons in walk, trot and canter in an arena, or jumping lessons with fences not above 0.80-1.00 m.

How widely riders at professional level varied in perception of intensity of training and fitness was an unexpected result of the showjumping study. A German dressage study (Schoneeissen *et al*., 2000) had similar findings. While not subject to statistical testing, showjumping riders with experience of training with international coaches, or contact with high intensity disciplines such as racing or eventing, were more inclined to include fitness canter and higher speed.

In contrast, one vital aspect of analysis of training in study I was that racehorse trainers in and outside the study had a consensus on classifying speeds. While showjumping riders in study IV appeared to be able to determine speed, they did not have the same consensus on intensity as racehorse trainers. This conclusion is based on a student data project using GPS measurements (Schöön C in manuscript). Detailed field testing of measurements such as heart rate, speeds and lactate would have added more objective measurements of work loads and fitness levels, but was outside the scope of the study.
One reason for the lack of consensus on intensity could be the choice of a Visual Analogue scale in protocols, as it is inherently subjective. An alternative could have been 'Borg Rating of Perceived Exertion' based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue (Borg, 1998). Criteria such as breathing rate and sweating could easily be transferred to horses by riders. Not only speeds but also training distance and use of intervals varied in showjumping fitness sessions, based on baseline interview data. Lack of fitness has been found to be a risk factor for injury in human athletes.

5.1.2 Volume

Volume of training is a result of frequency in relation to duration of sessions. Significant results from paper III suggested that a gradual introduction of new horses to the higher volume of work in riding schools was important, irrespective of previous fitness level. A gradual increase in training load is also an established recommendation for human athletes and racehorses. Volume of training for showjumpers and racehorses had a wide variation between yards.
Comparisons of volume of training between racehorses and riding horses were hampered by units use, i.e. furlongs cantered versus time ridden. In general riding school horses had 3-4 times the volume of work compared to showjumping horses, although at a different intensity. Volume of work as such appeared to have little influence on differences in incidence rate between riding schools, based on results from study III. One example of yard differences was the total time trained model reflecting volume for the showjumping horses,

where riders contributed 49% of the variation. In the showjumping horses volume increased with class competed, based on the total time trained model. This could be expected in professional yards, with young horses having a gradual introduction to training.

5.1.3 Variation

In contrast to volume and intensity, the effect of variation in equine training has not been addressed in racehorse training studies, and warrants exploration. Based on human sports literature variation in training is one factor that is stated to be of importance for reducing the risk of injury (www.IAAF.org). A study of Warmblood horses showed that competing in more than one discipline early in a horse's career increased its total number of years in competition (Braam *et al.,* 2010). Racehorses and riding school horses in general had low variation in their workload. Racehorses as a mean did canter training on a training gallop 5-6 days a week when in full training. However, in some racehorse yards horses in addition did up to 3000 m of hacking on roads to reach training gallops. Riding school horses did around 15 lessons weekly, all indoor during the winter season. Based on questionnaire replies, (lack of) variation was similar between riding schools. Different riding schools however had different strategies for jumping, and in strategies for outdoor hacking during spring and autumn. Jumping for riding school horses in combination with a high volume of work could be an example of the importance of balancing volume and higher loads, although this was not tested. The larger variation of training in showjumping horses could be one protective factor in the low incidence of injury in many study yards.

5.1.3 Rest and periodisation

Rest and periodization of training is a necessary part of training to allow adaptive processes as well as physical and mental recovery (www.IAAF.org). Results from paper III showed that horses in LUIO riding schools had longer mean summer rest at pasture, which could reflect the importance of periodization of training. Some showjumping riders in Sweden included summer pasture for horses < 7 years, following a peak of competition in the summer (data not shown). All three types of yards in general included a weekly rest day, with light exercise or paddock time. In study III some riding schools, chiefly in the LUIO group, had strategies where older horses (> 16-18 years) had reduced work, i.e. more rest. Some showjumping riders also had individual strategies for older horses.

5.1.4 Management

Management factors and farmer attitudes have been shown to influence injury and disease in herd level cattle and sheep studies. Based on the results of this thesis, the same seems to apply for horses. Paper III demonstrated that riding schools with highly qualified and experienced managers and chief instructors as a mean had low incidence of orthopedic injury. This is in accordance with results from previous studies both in horses and humans athletes (Reardon *et al*., 2011; Knowles *et al*., 2004). An earlier study of Swedish riding schools showed that experienced management had a protective effect against orthopedic injury (Magnusson 1973). In Thoroughbred racehorses in the UK being trained by a more successful trainer was protective against superficial digital flexor tendon injury in hurdle racing, compared with horses with less successful trainers (Reardon *et al*., 2011). Possibly associated with the level of competence was the finding that riding schools with low rates of locomotor problems were more likely to have more horses. Experience per se however did not necessarily have a protective effect for riding school horses unless coupled with certain management strategies, such as length of adaptation to riding school work. One potentially influential aspect not analysed in equine studies is the concept of 'animal eye', that is inherent understanding and focus on individual horses' needs and current condition. In the riding school study (III) the type of ownership was significantly different between the two insurance groups. The LUIO group had a majority of private owners, versus only club-run riding schools in the HUIO group. This could have influenced financial strategies, but such associations would require a separate study project to analyse.

While also difficult to classify, differences in strategies for horse recruitment could also potentially influence injury risk. For example conformation has been shown to influence injury risk. Choice of horses was a factor discussed both in the riding school questionnaire and showjumping baseline interviews. Showjumping riders and racehorse trainers had a homogenous selection of European Warmbloods versus Thoroughbreds. The horses had performance bloodlines with little variation between yards, except for studbook preferences in different countries in the showjumping study. Like racehorse yards, riders in general trained horses for other horse owners, including breeders. Riding schools in contrast had a wider range of horses, from Swedish Warmbloods, also bred on performance lines, to imports and crossbred horses of unknown parentage. Both LUIO riding schools and Swedish showjumping riders had a high percentage of Swedish Warmbloods. There were some contradictions on Swedish Warmbloods and wastage in results for paper II and III. In paper II Swedish Warmbloods had a higher rate of insurance claims compared to imports in paper II; results that were not reflected in paper III. The showjumping study did not have the scope to compare injury risk in different studbooks for Warmbloods. However, how horses have been raised potentially has influence on soundness. Traditionally conditions for raising foals and young horses have been thought to influence the quality of bone. This tradition has recommended keeping foals and young horses on good pasture with ample areas for natural exercise. The natural behavior of young horses with cajoling and running produce the intermittent high strains at high strain rates imposed in many unusual strain distributions recommended in experimental research for musculoskeletal adaptation. The effect of the opposite approach to raising foals was demonstrated in the study on Dutch Warmblood foals (Brama *et al.,* 2002; van Weeren *et al.,* 1999), where confinement produced a retardation of musculoskeletal development. Warmblood breeding in some areas of Europe use indoor barns to replace pasture, or small paddock areas rather than large pastures, although with differences between individual breeders. It can be speculated that this could have a negative influence on future soundness due to lack of early musculoskeletal adaptation.

5.2 Reflections on injury rate

Racehorses as a mean had the highest percentage of days lost of the two measured horse categories. While horses have a high athletic capacity, racehorses work is closer to the inherent maximum than showjumping or riding school horses, decreasing the margin of overload. As in human studies, one aspect of days lost measurements is reflecting the severity of injury. Fractures in racehorses require lengthy recovery and were not recorded in the showjumping horses. While not analysed, some riding schools had cases of traumatic fractures, through paddock accidents. While racehorses as a mean had the highest incidence of injury as measured by percentage of days lost, the range was 9 to 32.6 for the racehorse trainers and 0 to 21 percent for the showjumping riders. Thus racing yards with the smallest incidence of injury had an overlap with showjumping yards with the highest.

The same pattern of yard differences was evident for riding schools as for racehorse trainers and showjumping riders. While riding schools as a mean had a higher incidence rate of morbidity and mortality than the average horse owner, the riding schools in the LUIO group in study III had zero or low incidence rates of insurance utilization for locomotor and other problems. This was equivalent to showjumping riders with a low percentage of days lost (minding that time at risk and hence power was low for each rider). Some riding schools in contrast had an incidence rate of 3300 cases per 10,000 HYAR. While challenging to compare incidences from different designs, the highest incidences seem to be in racehorse yards. This high incidence rate subgroup (study II) had a major influence on the total mean incidence of riding schools being significantly higher than for the average horse owner with insurance. Paper III also showed that riding schools with low utilisation of insurance with experienced staff used early preventive action such as rest in case of early signs of lameness and did own preliminary evaluations before consulting a veterinarian (in non-acute cases), thus reducing veterinary costs and claims. Other riding schools with high utilisation of insurance cited having inexperienced staff who failed to recognize early signs of lameness.

While "lameness" is common when classifying days lost to training, dressage and racehorse yards have been shown to have days lost due to early signs of orthopedic injury such as joint effusion, but without overt lameness (Reed *et al*., 2011; Schoneissen 2000). This was supported by observations in study I, III and IV that some yards with experienced staff rest horses due to orthopedic signs without overt lameness. Observations in study I (data not shown) and by Reed *et al*., (2011) also show that a minority of trainers keep horses in work in spite of orthopedic symptoms, risking progression, while other trainers used a regimen of rest and reduced training. Among the findings by Reed *et al*. (2011) was a progression of joint injury grade when horses were kept in work, including on medication, while other horses did not progress past grade I classification (the lowest grade of joint injury), with reduction of training.

Failing to recognise, or ignoring, lameness signs can reduce the number of insurance claims or days lost, but lead to costlier claims or mortality over time. The racehorse study concentrated on fractures, which risk to progress to catastrophic fractures, if early signs are ignored (Nunamaker personal communication). Cohen *et al*. (1999) demonstrated a reduction of catastrophic racecourse injury by an expanded pre-race veterinary inspection of horses, not permitting horses with subtle signs of lameness to start.

This reflects one restriction in all estimations of incidence of mild disease injury; individual variation in criteria for and experience of lameness evaluation, especially mild cases. Keegan *et al*. (1998) showed a low correlation of assessment scores for lameness between clinicians and interns or residents and results from kinematic gait analysis. Independent testing of orthopedic health by clinical examination in a subset of the riding schools in study III (Egenvall *et al*., 2010) also showed inter-clinician variation in scoring.

One important aspect of days lost measures used in racehorse studies and IV is that they usually include all health events as judged by the trainer or rider, (in equine studies) or athlete/coach (in human sports studies). This produces a more complete picture of health events, compared to comparisons of only clinical diagnoses or insurance data. Including only cases with a diagnosis confirmed by imaging reduces the risk of misclassification, but exclude an analysis of total incidence of orthopedic health events, offered by rider, trainer (or athlete) based reports. Horses with days lost trained less also on days when healthy, which was difficult to interpret but could reflect adjustments in regimens for horses with recurrent health problems.

The orthopedic status of participating showjumping horses were subject to outside scrutiny, for example at veterinary inspections at competitions for showjumpers. In order to address the issue of subjectivity of reporting and misclassification Reed *et al*. (2012) used an expert panel to evaluate cases of carpal and MCP/MTP joint injuries in a prospective racehorse study. Trainer was significantly associated with joint injury occurrence. Incidence rates by trainer as rated by the panel ranged from 0.4 to 7.0 per 100 horse months. The panel also found trainer differences in the anatomical site and severity (category) of joint injury. Thus trainer differences were thus not solely based on evaluations by yard staff or individual veterinarians.

The aspect of age must be taken into account when comparing injury rate and work load between the populations. Age has been shown to influence injury risk in both racehorses, riding school horses and the general horse population. The three populations in the thesis had a wide range of ages, from two-year-old racehorses to riding school horses up to 30 years old, which can be expected to have influenced some differences in injury patterns. The clinical examination of horses in a subset of riding schools in the riding school study showed a significant association between age and orthopedic findings (Egenvall *et al*., 2010). It should be noted that they were not graded in severity and included minor findings.

5.3 Sequence of prevention

Measures to prevent sports injuries form part of what is called the 'sequence of prevention' in epidemiology. Firstly the magnitude of the sports injury problem should be identified and described in terms of incidence and/or severity (Bahr *et al*., 2003; van Mechelen *et al*., 1992). This step has been addressed for racehorses since the 1960’s. At yard level it was described as early as 1985 (Rossdale *et al*., 1985). For non-racehorses incidence of injury has been described in the general horse population, through for example insurance databases (Egenvall *et al*., 2006). Papers in this thesis were among the first to address yard differences for injury risk in riding horses. Secondly the factors and mechanisms which may play a part in the occurrence of sports injuries have to be identified (van Mechelen *et al*., 1992). Study I, II, III and IV described possible risk factors for injury from different angles. Papers III and study IV are among the first to describe training and management differences at yard level in riding horses.

The third step in injury prevention research is to introduce and test measures that are likely to reduce the future risk and/or severity of sports injuries. These measures should be based on aetiological factors and mechanisms identified in the second step (van Mechelen *et al*., 1992). Finally, the effect of the measures must be evaluated by repeating the first step (Bahr *et al*., 2003). Racehorse studies have reached this stage. Examples include significant reductions in incidence of injury from changing surfaces and inclines/declines on racing tracks in Scandinavia (Drevemo ref) and Japan (Oikawa *et a*l., 1994) or modifications of training regimens (Nunamaker 2000). Studies of riding and sport horses require further studies of incidence of injury and their risk factors in step I and II, as described by van Mechelen *et al*. (1992).

Results in this thesis thus offer no causative explanations and conclusive recommendations on risk factors, but findings that coupled with results from previous studies provide potential guidelines for riders, trainers and coaches to consider. To make comparisons across populations such as riding school-, showjumping- and racehorses that are inherently different in type of work, have offered new aspects on protective and risk factors respectively, and can potentially improve training advice.

Non-acute orthopedic disease in sporthorses is often referred to as “overuse” injury. Based on the inherent athletic capacity of equines it could be argued that riding for sport or pleasure hardly constitutes overuse in healthy horses. Many injuries could rather be said to be a result of “misuse”, in the meaning of training and management inappropriate for the horses’ age and expected performance.

Previous studies in racehorses, other animals and of human athletes have demonstrated that the musculoskeletal system needs longer time to adapt to exercise than the respiratory or cardiovascular system. This adaptation thus must be gradual, and also targeted to the work expected in different disciplines. Results in the thesis support previous studies showing that differences in injury rate between yards are associated with differences in training strategies and how appropriate they are for the type of work expected.

5.4 Statistical considerations

To obtain valid estimates of the effects of interest in population studies clustering must be taken into account. Clustering is usually expected to lead to dependence between the responses of observations in a group (or cluster) because the shared feature makes the outcome 'more similar' than otherwise. One general effect of ignoring clustering is that the standard errors of parameter estimates will be wrong and often too small. This is particularly true if the factor of interest is a group level factor. Whenever data are collected from individuals that are managed in a group, such as yards, we should suspect that the data might be clustered (Dohoo *et al.,* 2010). Clustered data can be analysed at the cluster level, i.e. directly at herd-level. Another approach is to take account of clustering at various levels in the data (multilevel modeling) using fixed or more commonly random effects. Using the latter approach risk factors at different levels can be assessed. In the thesis random effects were used in paper I and IV, and its analogue for survival analysis in paper II (frailty effect). In study III the majority of the analysis was done at herd level. Unfortunately study III was too small to allow multivariable analysis, which would have allowed testing of associations between manager/instructor experience and other factors. This thesis has discussed between-yard variation in days lost in study I and IV. In study IV however formal validation of the concept is in manuscript format (Egenvall et al., in manuscript). In study I aspects of injury has also been presented in separate papers. A paper specifically on days lost data in a subsequent bone biomarker study by the same research group has been published, with similar findings (Dyson *et al.,* 2008).

5.4.1 Possible sources of bias

Bias is a potential complication in all epidemiological studies. The most important biases are those produced in the definition and selection of the study population, data collection, and the association between different determinants of an effect in the population. The main types of bias are selection bias and information bias (Dohoo *et al*., 2010)

Potential for selection bias can be found in study I and IV, because selection of convenience rather than random samples were made. The potential of collaboration was a secondary but necessary criterion in selection, due to the high level of workload and commitment necessary in participants. In study III selection of riding schools with high versus low incidence of insurance claims could have been conducted in a number of different ways. With the selection made, some riding schools were high versus low in only one of the morbidity (veterinary care)/mortality categories. Making selections based on only morbidity or only mortality could potentially have influenced results in other directions. Another main type potentially affecting validity is information bias. One potential misclassification in these studies was if a horse was classified as sound when lame from an orthopedic problem. A source of systemic bias relative to diagnostic decision making, was that several participating racehorse yards, and to some extent the study IV showjumping yards, consulted the same veterinarian(s) and clinics. An aspect that was checked carefully, but may still remain as a minor problem in the data, is the classification of days lost versus rest days. Some horses rested, or had very light exercise, for rather long periods without any information about health problems. Some of these horses may for example have had minor orthopedic problems. Recall bias is another aspect in retrospective studies, such as study III. Data validity issues are always of concern using secondary insurance data. However, the equine diagnostic insurance data have been shown to correlate rather well with veterinary records in clinics (Penell *et al*., 2005).

5.5 Other limitations

The papers in the thesis were primarily focused on training and management, and injury. In paper I and IV health data was registered as part of the study, and described in the thesis. Surface use has been shown to be an important influence on injury risk together with training. In study I it was registered but left outside the analysis due to restrictions in the model. In study IV surface data will be presented elsewhere (Egenvall *et al.,,* in manuscript)

Based on treadmill studies the results in study I could be interpreted as showing that fast work increases bone density. This was not tested by non-invasive methods, such as computed tomography, because imaging methods measuring bone density were unavailable for large-scale use (I).

Study III was in essence a pilot study. A larger study would have allowed testing of various management factors as predictors in multivariable analyses and analysis of interactions, for example between manager experience and size of riding school. In addition, a prospective study as in paper I and IV would allow registration of workload at horse level also in riding schools. The study questionnaire included questions with the intention to quantify intensity of lessons including level of difficulty, but wording proved to be too unspecific to allow a grading or analysis.

The compliance of the showjumping study was lower than expected, with a dropout rate of 50 percent based on all countries within 2 months from recruitment. Compliance was influenced by time restraints for participating riders, but varied by country and appeared to be influenced by selection criteria and co-worker availability. As an example, electronic protocols for the riders were tried in Sweden but three of four riders who used this cited difficulties in handling the electronic protocol version and were lost to the study. Gathering data through diary protocols offer challenges of other types than questionnaires administered at a point in time and experiences from study I was used designing study IV. For example it is important to maintain compliance in recruited individuals and to ensure the same quality of data recording through time, through for example data checks and follow-up calls. For example in a few yards evaluating rest versus days lost was challenging, and hence addressed by frequent datachecks and follow-up calls. In human sports studies there are few publications based on longitudinal training data registered by athletes in individual sports (Jakobsson *et al*., 2010).

As a comparison the compliance by recruited racehorse trainers in prospective studies was 90-100 percent at yard level (Verheyen *et al*., 2006; Dyson *et al*., 2008; study I). The response rate in a retrospective racehorse study, based on completion of telephone questionnaires was over 94 percent (Parkin *et al*., 2004). In contrast a retrospective dressage study, using a postal questionnaire, in the UK (Walters *et al*., 2008) had a response rate of 11 percent. This study was based on all members of a specialist association (British Dressage) and the questionnaire was administered with the associations' magazine. This suggests compliance is more difficult to obtain in the equestrian disciplines compared to in Thoroughbred racehorse training. One major difference between the disciplines was the availability of staff in racing yards. Trainers delegated diary entries to head stable staff or trainer assistants, while in the showjumping study a majority of riders did own entries, without assistance. Study design could also have been a major influence, both in the retrospective questionnaire studies and prospective field studies, eg. because of differences in the way retrospective questionnaires were administered. Study I and other racehorse studies (Reed *et al*., 2011, 2012; Dyson *et al*., 2008) have included monthly or bi-monthly yard visits, offering participant support and feedback. Study IV included return visits to some yards for pilot testing of training surfaces, and telephone contact, but no planned regular meetings with riders during the data acquisition period. However between the two Swedish seasons follow-up visits were made to the riders for surface testing.

It is also interesting to note that it was difficult to achieve exact the same study design in all countries in study IV. For example the inclusion criteria were slightly different between the countries, which also directly hamper between-country comparisons. Similar experiences were made studying cows in international observational studies (Wolff 2012).

6 Conclusions

- While equine orthopedic injury is a major cause of morbidity and mortality in the three studied horse populations, based on different levels of measurement the risk varies between yards within the populations (I, II, IV)

- The showjumping and racing yards populations have significant between-yard differences in exercise regimens including volume and variation (I, IV)

- In two-year-old racehorses cumulative high speed training was associated with a decrease in bone turnover, interpreted to reflect an increase in bone density (I)

- Patterns of bone turnover varied significantly between racehorse training yards, indicating between-yard differences in skeletal adaptation to training (I)

- Rates of insurance utilization varied substantially among riding schools (II)

- Ponies had lower incidence of utilization of insurance than horses > 148 cm (II)

- Riding schools with a low level of wastage due to locomotor problems were more likely to have experienced and highly trained managers and instructors (III)

- Riding schools with low level of wastage due to locomotor problems were more likely to have > 11 weeks of gradual introduction of work for new horses and summer rest > 4 weeks

- Different horse populations differ in time lost to training due to injury, incidence of injury and types of diagnosis (thesis)

- The between-herd variation and identified management factors indicate that incidence of injury in race- and riding horses can be reduced by modifications in management and training (I, II, III, IV)

7 Future studies

There is much potential for continued cooperation between epidemiological, musculoskeletal and other scientific equine groups in training studies. This potential for detailed study includes testing effects of surface properties, as pioneered for riding horses within the showjumping study (IV). It also includes feeding regimens and genetics, and associations between bone and joint metabolism and injuries, and last, but not least, combined studies testing the physiological effects of training on cardiovascular, muscular and skeletal adaptation to training in the same animal, investigating an optimum balance of training for cardiopulmonary and musculoskeletal fitness, for optimum and sustainable performance.

Data from the showjumping study will be analysed and described further, including for surface use and relation to days lost, competition strategies etc.

Further exploration of how training elements in different disciplines could be incorporated in and improve exercise regimens in other equine fields is warranted. For example individual training regimens were observed for showjumping horses but less in riding school- and racehorses. There is thus scope to extend comparisons between horse populations and disciplines, concerning risk factors for injury, aimed at producing advice to optimize training for soundness in different disciplines.

That rider and trainer or manager skills may influence orthopedic health and wastage was an important observation. For example the low percentage of days lost to training found in the showjumping horses in study IV, and the apparent influence of riding instructor on orthopedic health of riding school horses, warrants further study. The incidence of injury and training regimens of the showjumping horses should be compared to the same parameters in riders at lower levels of experience and qualifications.

One aspect of soundness in racing and equestrian sport including showjumping is prevention of banned medication use. Increased awareness and focus by the equine industry on prevention of injury in sport horses could potentially also help reduce cases of banned medication and use of supplements.

8 Populärvetenskaplig sammanfattning

8.1 Bakgrund

Hållbarhet är en stor fråga inom hästvärlden. Ortopediska skador är den vanligaste orsaken till utslagning av hästar. Bristfällig exteriör, utfodring och uppfödningsförhållanden är bland de faktorer som anses kunna påverka hållbarheten negativt. Men de senaste decennierna har forskning inom veterinärmedicinsk epidemiologi alltmer inriktats på att identifiera andra riskfaktorer, som till exempel hur hästen tränas. Epidemiologi är enkelt uttryckt läran om sjukdomsmönster och vad som orsakar dem. Syftet med epidemiologiska studier är alltså i förlängningen att förebygga skador eller sjukdom.

Studier inom galoppsporten har visat att t ex underlag och existerande lindriga skador är viktiga riskfaktorer för allvarliga skador i löp. Men forskarna har också kunnat konstatera att skaderisken varierar mellan olika träningsupplägg och mellan olika träningsstall. Det finns hittills få motsvarande studier på ridhästsidan. Inom lantbruket har epidemiologiska studier på t ex mjölkkor och får visat att det finns skillnader på gårdsnivå som påverkar djurhälsan.

Syftet med studierna i avhandlingen var därför att kartlägga skillnader i träningsupplägg, skötselfaktorer och skaderisken mellan olika stall inom områdena galopp, ridskola och banhoppning.. Kombinationen av tre olika hästtyper I materialet gav möjligheter till jämförelser mellan olika hästdiscipliner som knappast gjorts tidigare. Dessutom mättes hur skelettet svarar på olika träningsupplägg hos tvååriga galopphästar

8.2 Studier och resultat

Studierna i avhandlingen började med en kartläggning av träningsupplägg för galopphästar i England. Tio galopptränare deltog, med från början nära 200 tvååriga fullblodshästar. De registrerade daglig träning under tio månader, motsvarande en hel säsong. Totalt analyserades 43 373 träningsdagar. Dessutom togs blodprover på hästarna för analys av skelettmarkörer, som avspeglade hur hästarnas skelett svarade på den träning de fått. Studien visade på betydande skillnader i träningsupplägg mellan tränarna, både i volym av träning och intensitet, mätt i galopptempo. Högintensiv galoppträning hade signifikant effekt på skelettbiomarkörerna. Tidigare studier har visat på ökad bentäthet och minskad frakturrisk med högintensiv träning som motsvarar löptempo. Andelen förlorade träningsdagar på grund av sjukdom eller skada på hästarna varierade från 9,2 till 32,6 procent mellan olika tränare.

I nästa studie överfördes fokus på ridhästsidan i Sverige, genom att analysera försäkringsdata för ridskolehästar. Försäkringsbolaget AGRIAs databas användes för att jämföra skadeutfall mellan ridskolor åren 1997-2002. Studien baserades på data om 5140 hästar, eller omkring hälften av Sveriges ca 10 000 ridskolehästar. Svenska halvblod var den största enskilda rasgruppen, men totalt var ca 40 raser representerade. Medan ridskolehästar i genomsnitt hade något mer försäkringsuttag än genomsnittshästen, så var variationen stor mellan de 139 ridskolor som ingick i undersökningen. I genomsnitt hade ridskolorna 1116 försäkringsfall räknat på 10 000 hästår för veterinärvård av ortopediska skador.

Syftet med den tredje studien i avhandlingen var att få närmare inblick i ridskolor med det högsta och minsta försäkringsuttaget pga ortopediska skador. Studien inriktades på stora hästar, oräknat ponnyer. Ponnyer har I tidigare analyser av försäkringsdata haft ett mindre försäkringsuttag än hästar > 148 cm. Till studien valdes 20 ridskolor av de 139 i den första försäkringsstudien, 19 deltog sedan. De med lågt försäkringsuttag hade i snitt 192 försäkringsfall (veterinärvård) per 10 000 hästår, jämfört med 1116 för genomsnittsridskolan och 3396 för ridskolorna med högst uttag. Ridskolorna besöktes på plats och besvarade en omfattande enkät om olika strategier. Den visade att ridskolorna med lågt försäkringsuttag, indirekt ett mått på lite skador, i högre grad hade en mer erfaren ridskolechef och mer välutbildade chefsinstruktörer. Ridskolorna med litet försäkringsuttag hade också i högre grad invänjningsperioder på minst elva veckor för nya hästar, innan de sattes in i full lektionsverksamhet, och minst fyra veckors sommarbete. Ridskolorna med lågt försäkringsuttag var oftare privata än föreningsdrivna, och större, räknat i antal stora hästar.

Avslutningsvis kartlades träning och skadeutfall hos hopphästar hos ryttare på professionell nivå, på motsvarande sätt som i den första studien av galopphästar. et var ett internationellt samarbetsprojekt med ryttare i Sverige, Schweiz, Storbritannien och Holland. Totalt analyserades data från 31 ryttare med 263 hästar, alla europiska sporthästar, med sammanlagt 39 262 träningsdagar. Ryttarna registrerade dagligen hästarnas arbete. De olika aktiviteterna var markarbete, longering, uteridning, hoppträning, konditionsträning i galopp, konditionsträning med klättring i backe och tävling. Som för galopptränarna var det stora skillnader mellan ryttarna i deras träningsupplägg, både i volym och val av aktivitet. Ryttarna gjorde i medel mellan 4.6 och 6.2 träningspass i veckan. Ett exempel på skillnader i upplägg var andelen uteridning. Det varierade beroende på ryttare från fem till 47 procent av den totala träningstiden.

Förutom träning och arbete jämfördes också utevistelse och annan aktivering. I galopphäststudien analyserades enbart träningen, men tillgänglig data visade att de flesta av galoppstallen använde skrittmaskiner. Få hästar hade däremot utevistelse i paddock eller hage. Alla ridskolor i den pilot/fält svenska pilot/fält studien hade daglig hagvistelse för sina hästar, i medel 4,3 timmar. (Detta var 2006, innan daglig hagvistelse blev obligatoriskt för svenska hästar). Bland hopphästryttarna använde alla utom tre skrittmaskin. Alla de svenska deltagarna, och de flesta i de andra tre länderna, hade daglig utevistelse som rutin för sina hästar. Genomsnittstiden var knappt 4 timmar, men med stora variationer mellan ryttare och mellan länderna. Räknat på den tid som hopphästarna dagligen tillbringade utanför sin box varierade den från 1.3 till 11.3 timmar i snitt mellan hoppstallen.

Hoppstallen i studien hade i genomsnitt liten förlust av träningsdagar, vilket användes som mått på skade- och sjukdomsutfall. För flera ryttare var siffran förlorade träningsdagar bara runt en procent, medan medel för hela gruppen var sex procent och 21 som högst. Vanligaste diagnosgruppen var ortopediska skador inklusive ryggproblem, som stod för drygt hälften av fallen. Näst vanligast var medicinska åkommor och olyckor.

Skillnaderna mellan de olika hästtypernas användningsområden avspeglades i skillnader i arbetsprofil räknat i volym, variation och intensitet. Översiktligt sett hade ridskolehästarna hög volym av arbete jämfört med de andra två grupperna, men med låg intensitet och variation. Galopphästarna hade i jämförelse liten volym och variation men hög intensitet i träningen, och hopphästarna medelhög volym och intensitet, och större variation jämfört med ridskole- och galopphästarna.

8.3 Slutledning

Avhandlingens resultat stöder tidigare studier som visar att ortopediska skador är den viktigaste orsaken till skadeuppehåll och utslagning av hästar. Resultaten stöder också tidigare studier som visar att skaderisken samtidigt varierar mellan olika stall. Avhandlingen visar för första gången jämförelser mellan skadeutfall inom olika hästdiscipliner. Skadeutfall specifikt för hopphästar och ridskolehästar på besättningsnivå har inte analyserats tidigare. Resultaten i avhandlingen visar också att träning och skötsel skiljer sig mellan olika ryttare och tränare respektive ridskolor. De tre huvudkomponeneterna i träning som kombineras olika mellan stall och mellan grenar är intensitet, frekvens och träningspassens längd. De två sistnämnda ger tillsammans volym. Resultaten är i överensstämmelse med tidigare häststudier som visat att skadeförekomst påverkas av skillnader i träning och management. Resultaten i galoppstudien överensstämmer också med tidigare undersökningar som visar att rörelseapparaten anpassar sig olika beroende på träningsupplägg. Skelett och brosk behöver längre tid för att anpassa sig till ökad arbetsbelastning än t ex muskler.

För att främja hästens hållbarhet bör alltså träningsuppbyggnaden vara gradvis, och avpassad för den typ av arbete som krävs i olika typer av grenar. Då analys av träningsfaktorer och skador på ridhästsidan är ett nytt område krävs ytterligare forskning för att öka kunskapen om hur skador uppstår och kan förebyggas. Baserat på resultaten i avhandlingen och andra studier finns dock en rad aspekter att ta i beaktande ur hållbarhetssynpunkt. Det inkluderar ryttaren/tränarens utbildningsnivå och erfarenhet, stegvis upptrappning av träning, träningsinslag som främjar kondition och motsvarar ansträngningsnivån på tävling samt variation. Det gäller både av aktiviteter och kraven på belastning, även kallat periodisering.

9 References

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Acknowledgements

This work was carried out at the Division of Ruminant Medicine and Veterinary Epidemiology, Department of Clinical Sciences, in collaboration with the Department of Equine Science, Swedish University of Agricultural Sciences, Uppsala, Sweden (papers II, III and IV) and the Department of Veterinary Basic Sciences, The Royal Veterinary College, London, UK (paper I).

Funding was generously provided by The Animal Protection Board and Swedish Humane Society, Kronoberg branch (riding school project), the International Equestrian Federation (FEI), Switzerland, the Swedish-Norwegian Foundation for Equine Research, Sweden and UK Sport Lottery Funding for the British Equestrian Federation World Class Programme, UK and most important for my role, World Horse Welfare, UK (show-jumping project). The racehorse study was funded by the Horse Betting Levy Board, UK.

This thesis would not have been possible without the help and support from many people. In particular I wish to express my sincere gratitude to:

Professor Agneta Egenvall, my main supervisor, for invaluable dedication to the riding school and show-jumping project, for support by generously sharing enormous statistical and epidemiological expertise, and attention to detail throughout the process.

Professor Lars Roepstorff, associate supervisor, for dedication to the riding school and show-jumping project, setting up the show-jumping study as an international collaborative project, providing biomechanical and computer expertise, lively discussions and important thesis feedback.

Johan Bröjer, associate supervisor, for cheerful and invaluable support, wise scientific and writing advice, and strengthening discussions with training physiology knowledge.

Kia Nostell, associate supervisor, for cheerful and invaluable support, expert chairing of meetings, wise scientific and writing advice, and strengthening discussions with training physiology knowledge.

London supervisors, Professors Jo Price, Allen Goodship and Dirk Pfeiffer for sharing their vast knowledge, providing my scientific grounding, and to Jo for a fantastic opportunity.

Chris Johnston, for participation in the riding school project and aiding the setting up of the showjumping project as an international collaborative project

The UK trainers and their staff for opening their yards, invaluable work for the project and their kind hospitality during visits.

The participating Swedish riding schools for generously taking time to welcome me for the questionnaire visit, and follow-up queries

The showjumping riders in Sweden, Netherlands, Switzerland and the United Kingdom, for invaluable work for the project, and for the Swedish riders' kind hospitality at the baseline visits. To work with all study yards was a privilege.

Brendan J and Kristien V in the UK, for being very good colleagues in the racehorse project and friends since.

Showjumping project co-workers Rachel Murray and Carolyne Tranquille in Newmarket, Annmarie Oomen and Rene van Weeren in Utrecht, Caroline Bitschnau, Stephane Montavon and Mike Weishaupt in Zurich, for interesting and good company at meetings and conferences, and invaluable input in the project. Special thanks to Carolyne T, for sharing an interest in showjumping and racing, and great hospitality in Newmarket.

Elin Hernlund, allmänt exceptionell person och med-doktorand, inklusive för trevligt och glatt sällskap på resor, och Hippologens mdarbetare, särskilt Jane för hjälp med Tur och Retur.

Nuvarande och tidigare doktorandet på IME: Marie, Nils, Charlotte, Lena, Anna, Emma, Malin, Helena O, Cecilia W och Karin A, för alltid roligt och intressant sällskap. Särskilt till Karin som kurskamrat och Cecilia för hjälp och uppmuntran under kappans slutförande.

Professor Ulf Emanuelsson, en klippa , och alla deltagare vid Epiforum.

Plus alla andra på IME med avdelningschef Camilla Björkman I spetsen, för att ni tillsammans gör det så kul att gå till jobbet !

Kjell-Åke Ahlin for ovärderlig dator- och internet support

KC-bibliotekets personal med Mikael E i spetsen, för snabb och hjälpsam service

Göran och AnnMarie Dalin, för referensbrev till Animal Health Trust som ledde till London, och organiserandet av mitt Erasmusutbyte I Utrecht, som blev början på mitt intresse I epidemiologi.

Tidningen Ridsport med personal och medarbetare, för långvarigt och roligt samarbete, som öppnat många dörrar i hästvärlden.

Stig, Gunvor och grannar, som står för en oas på landet respektive hjälp med Summer

Fantastiska vänner, inkl kursare, utanför jobbet, Annica och Albert, Bitte och Jonas, Caroline och Björn, Marina och Rick, Lena och Peter, Lotta, Lisel, Åsa, Lena, Eva och Fredrik, Åsa C, Sofia B, och fler, som tillsammans egentligen förtjänar hela egna sidor ! Det inkluderar Lolo och Ken på Irland och Philippa i England, som från första början satte mig på det här spåret.

Pappa, mamma, Lotta, Lars, Mathilde, Madelen, Kerstin, Hans, Helene, Jan och andra familjemedlemmar, för att ni finns där och för stöd längs vägen

Och förstås Summer, ständig källa till glädje!