AN EPIDEMIOLOGICAL STUDY OF THE FACTORS AFFECTING THE PERFORMANCE OF RACING THOROUGHBREDS AT THE HONG KONG JOCKEY CLUB

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

by

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ABSTRACT

AN EPIDEMIOLOGICAL STUDY OF THE FACTORS AFFECTING THE PERFORMANCE OF RACING THOROUGHBREDS AT THE HONG KONG JOCKEY CLUB

The objective of this research project was to investigate the reasons associated with the premature retirement of Thoroughbred horses in training at the Hong Kong Jockey Club (HKJC) and to develop intervention strategies in an attempt to reduce training and racing injuries.

The impetus for this project was a survey aimed at identifying the reasons for a decline in the race attendance and betting revenue. This identified premature retirement and an increase in turnover of horses which reduced the opportunity to "get to know " individual horses as one of the reasons for the decline.

Content analysis of reasons for retirement identified superficial digital flexor (SDF) tendon injury as the major reason for the premature retirement in this population accounting for a mean of 3.2% of the total. The mean annual cumulative incidence of retirements due to SDF tendon injury was 3.2% accounting for 14% of all retirements.

A follow up descriptive analysis of retirement of Thoroughbred racehorses due to tendon injuries at the Hong Kong Jockey Club (1992–2004) provided population based data on the frequency, career and economic losses associated with tendon injury induced retirement. The risk of tendon injury increased over the 12 year period from 2.3–4.2%. The length of the racing career, number of starts and earnings of horses retired with tendon injuries were reduced by 25.6, 41.2 and 53.3%, respectively.

Further evaluation of detailed training data (1997-2004) to identify risk factors for retirement because of tendon injuries in Thoroughbred racehorses was undertaken. Conditional logistic regression analyses were performed to identify risk factors for retirement from racing attributable to tendon injury. Two multivariable conditional logistic regression models were

created. Results suggest that resources focused on obtaining accurate training data may be misdirected in the absence of internationally agreed criteria for incident tendon injury among racehorses. Nevertheless, changes in training intensity and findings of previous clinical examinations could be used to identify horses at risk of tendon injury–associated retirement

One of the by-products of this process was the identification of a population of horses which were absent from the race track for protracted periods of time but were not evident on the clinical database as suffering from injury or disease. At the time, injured horses, once identified were required to have an Official Veterinary Examination (OVE) before they were allowed to race again. This information was published and considered by some trainers to have a negative impact on public perceptions of the horse and owner's opinion of the trainer. Consequently it was possible that this population of horses, which were absent from racing, had injuries which may have been minor but which were not presented for veterinary examination. In consultation with trainers, a new unpublished category was introduced. The "To watch" category included horses that were absent from racing and training.

The impact of the intervention strategy by introduction of the track work and race monitoring system and the "To watch" category was reviewed by assessment of the number of pre-race inspection failures; the number of official veterinary examination (OVE) notices issued and the number of horses in the "To-watch" category.

There was a reduction in OVE of from approximately 0.8 events per horse per racing season to 0.56 OVEs per horse per racing season. The total number of OVEs and "To Watch" notices given out exceeded the OVEs in the year before introduction indicating that an additional 0.4 event of illness and injury events in horses that were not previously monitored were being identified by this process.

This thesis concludes with a philosophical view point on the veterinary management of Thoroughbred racing injuries in which a "Think-out-of-the box" concept in assessing the risk of racehorse injuries is discussed. One outcome of this is an integrated technology approach for tracking horse performance. By allowing standardised recording and review of detailed training and biometric data of individual horses this will assist future development of Intervention

Strategies (for example, alteration of training pattern for Trainers with high injury rates in an attempt to reduce risk of injury). In addition development of predictive mathematical models to provide risk indicator system in the form of 'traffic lighting' for different risk zones (Green for low risk; Yellow for moderate risk and Red for high risk) can be explored to raise awareness of trainers to subject racehorses to veterinary monitoring in continual full training programme to optimise racing performance and health welfare.

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Special Thanks also to my dear Austrian wife Susi and my two boys Lukas and Oliver for their family support on my full time job duties at the Hong Kong Jockey Club and my part-time PhD study.

CHAPTER 1

Introduction

This is a collaborative project between the Department of Veterinary Regulation and International Liaison, the Department of the Veterinary Clinical Services at The Hong Kong Jockey Club (HKJC), Hong Kong, and the Faculty of Veterinary Science at the University of Liverpool, UK. This study was part of a programme to optimise the longevity and the health and welfare of the Thoroughbred racehorses in Hong Kong. The Hong Kong Jockey Club has been recording daily data on horse racing records since 1979 and training data since 1997. The project concept was initiated by review of evidence based references on equine wastage and injuries in training and racing of sports horses.

Longevity is of economic importance in the Thoroughbred racing industry because of expenses and time invested in breeding and training. In spite of the high costs invested in racehorses, there have been few earlier studies of risk factors that can affect length of racing careers of Thoroughbreds (Jeffcott et al. 1982; Rossdale et al. 1985; Bailey et al. 1997; Wilsher et al. 2006). Tendon injury is one of the most common causes of wastage in the performance horse; the majority of tendon injuries occur to the superficial digital flexor tendon (Kasashima et al 2004; Wilsher et al. 2006; Thorpe et al 2010). The age-related risk in tendon injuries provides further support that overstrain injuries are associated with accumulated degeneration. These data provide a valuable resource for further research into the aetiology of tendon injury in the racehorse (Kasashima et al 2004). Thorpe et al (2010) conducted a review to outline the epidemiology and aetiology of equine tendon injury, the different functions of the tendons in the equine forelimb and suggested possible reasons for the high rate of failure of the superficial digital flexor tendon. An understanding of the mechanisms leading to matrix degeneration and subsequent tendon gross failure is the key to developing appropriate treatment and preventative measures. However there is currently limited information regarding the number of races and the period for evaluation of outcome which is critical for assessment of tendonitis treatments (O'Meara et al 2010).

Knowledge of factors that influence longevity is crucial for optimization of the training methods aiming at reducing wastage which refers to losses that occur at racing industry. An understanding of the role of some factors may help owners, trainers and other equine professionals to optimize the performance of the horses under their care.

A number of studies have been published aimed at reducing the risk of injury to Thoroughbred racehorses and eventing horse in the UK (Parkin 2000, 2003, 2004a, 2004b, 2004c, and Pinchbeck et al 2002, 2003, 2004). In addition to the horse's medication history and the state of any pre-existing injuries and degenerative conditions, the cumulative musculoskeletal stresses of training and racing have been considered as a significant risk factor (Cruz et al 2007). Many other risk factors for racetrack and training injuries in Thoroughbred racehorses worldwide have also been documented by different research groups to address the equine welfare concern for horse wastage in the racing industry. Parkin (2008) has conducted a review of risk factors for training and racetracks injuries with a list of evidence based references (Table 1). These projects have involved the analysis of retrospective data and the design and analysis of prospective cohort and case control studies to provide references for development of rational risk reduction strategies.

Table 1 - Review of risk factors for Racetrack injuries in Racehorses (Parkin 2008)

Reported Risk Factors for Musculoskeletal Injuries	**References**
1. The gender of the horse Horses to be prevented from racing (It is not realistic to expect male or female horses to be prevented from racing because of risk of injury. However these variables should be included in multivariable models to account for the confounding effect they may have on other risk factors within the model.)	Estberg et al 1998 Hernandez et 2001
2. Total distance accumulated during a 2-month period was positively associated with the risk of catastrophic musculoskeletal injury.	Estberg et al 1996
3. The risk of catastrophic musculoskeletal injury was greatest within 30 days of a period of above average high-intensity exercise. • A period of high-intensity exercise was defined as a 60-	Estberg et al 1998

day period where the average daily high-speed distance accumulated was greater than the seventy-fifth percentile cut-off for the population. • The authors calculated that this level of high-speed exercise equated to approximately 25 furlongs (5km) per 30-day period (approximately 5.8 furlongs (1.2km) per week.	
4. A longer interval since the last 60-day-plus period without a race (ie. lay-up) and the distance exercised in the last month (suspensory apparatus failure) or 2 months (condylar fracture of the third metacarpus) were associated with an increased risk of these outcomes. • For every extra day since the last 60-day plus lay-up the odds of condylar fracture of the third metacarpus increased by 0.3%. The odds of suspensory apparatus failure remained level for up to 120 days since the last 60-day-plus lay-up, but increased thereafter: 3.4 times for periods between 121 and 214 days since the last 60-day-plus lay-up; and 5.9 times for periods greater than 320 days since the last 60-day-plus lay-up. • For every extra furlong exercised at fast pace the odds of suspensory apparatus failure or condylar fracture of the third metacarpus increased by 4%.	Hill et al 2004
5. Multiple measures of exercise intensity were all positively associated with the outcome for proximal sesamoid bone fracture. • For example, case horses were more likely to spend more time in active training and racing, complete more exercise events, have higher exercise intensities in the 12 months before the case date, and have exercised further during their career.	Anthenill et al 2007
6. Associations between the risk of fracture in training or racing and exercise distance over relatively short time periods identified in UK. • Horses that exceeded 220 furlongs (44 km) at canter (<= 14 m/s) and 30 furlongs (6 km) at gallop (> 14 m/s) in a 30-day period were at the highest risk of fracture. This level of gallop and distance exercise equates to approximately 7 furlongs (1.4km) per week. • The risk of pelvic or tibial stress fracture increased with increasing distance cantered up to a maximum at around	Estberg et al 1998 Verheyen et al 2006a Verheyen et al 2006b

250 furlongs (50 km) per 30-day period. The association with the distance galloped compares closely with that reported in California (25 furlongs per 30-day period), even though the case definitions were quite different, providing stronger evidence of a potentially casual association.	
7. The association between average distances exercised at fast pace and musculoskeletal injury has been demonstrated in a study of 2-year-old Thoroughbred horses in Australia. • These authors used a cut-off of speeds greater than or equal to 800 m per minute (approximately 13.3 m/s) to indicate fast work. Horses that had a greater percentage of fast work days during their first fast work preparation were more likely to sustain a musculoskeletal injury that ended the training preparation. • The average distance trained at speeds greater than or equal to 800 m/min was also positively associated with musculoskeletal injury.	Cogger et al 2006
8. In a further study from Australia that investigated fatalities in flat racing, high-speed distance accumulated during the period 31 to 60 days before a race start was most important in determining the likelihood of fatality.	Boden et al 2007b
9. In jump racing, the total number of career starts and having started more than once in the 14 days before the case race were both associated with an increased likelihood of fatality. • Although these studies used a broader case definition of "fatality," it was previously reported that most cases were caused by musculoskeletal injury and it is most likely that this result is caused by the effect of exercise on the skeleton, as in the previous studies. • The differences in hazard period between these studies may be caused by the broader case definition or local differences in the racing population and racing and training practices.	Boden et al 2006 Boden et al 2007a
10. Association between increased amounts of high-speed exercise and the risk of several musculoskeletal injury case definitions have been identified in several studies. • These findings are consistent with the hypothesis that horses doing a lot of this type of exercise are also accumulating subclinical or clinical bone damage that can	Poole et al 1990 Stover et al 1992 Riggs et al 1999a Riggs et al 1999b Kawcak et al 2000 Hill et al 2001

result in a catastrophic outcome. • Adaptation in the racehorse is principally influenced by the training schedule to which the horse is exposed. Structural changes to the distal condyles of the third metacarpus and metatarsus of horses in race training have been observed and more specifically the subchondral bone of this region has been shown to undergo an adaptive response to high-speed exercise.	
11. Observed association between low exercise distance and increased risk is a healthy horse effect, whereas the association with longer racing distance is caused by accumulation of microdamage and subclinical injury.	Estberg et al 1996 Estberg et al 1998 Hill et al 2004 Perkins et al 2005b Cogger et al 2006 Verheyen et al 2006a Verheyen et al 2006b Boden et al 2007b
12. Risk of injury after a lay-up period- A strong association between risk of humeral fracture and the number of days since the end of the last 60-day-plus lay-up was demonstrated in racehorses in California. • Using a case-crossover design, where cases act as their own controls at a prior point in time, a hazard period of 10 days following a 60-day-plus lay-up was identified as being most significant with respect to the risk of fracture. • The authors hypothesized that this may be caused by the fact that osteoclastic resorption has taken place but osteoblastic remodeling is not yet complete. • Horses returning to exercise before the remodeling process is complete (about 3 months) may have bones that are less able to withstand training load than before the lay-up period. • Exercise is believed to suppress the resorption of bone, as the initial part of the reparative process, preventing a reduction in bone strength while the horse continues to train.	Pentecost et al 1964 Carrier et al 1998
13. Horses with greater than 32 days since their last race were 2.5 times more likely to have a catastrophic musculoskeletal injury during racing, compared with horses with less than 14 days since their last race.	Bailey et al 1999

• The problem with this and other similar studies is the lack of information on the exercise activity between races (ie, in training). It is difficult to be sure that the increase in risk was associated with changes in bone structure during a true lay-off period and not an effect of pre-existing injury that prevented an appearance on the racecourse at any earlier date.	

Research Opportunities at the HKJC

The HKJC conducted a public survey of 1500 punters at Off-Course Betting Centres in 2004 and revealed that 22% attributed the decrease in betting turnover to the high turnover of horses. The respondents indicated that they were "Unfamiliar with new horses." Other reasons for causes of reduction in betting turnover are listed below:

- 57% respondents indicated "Poor economy/ less spare money"
- 35% respondents indicated "Inconsistent horse performance (e.g. injuries)"
- 16% respondents indicated "Too many lower class races"

The Hong Kong Jockey Club collects, stores and maintains a large volume of data for all horses trained in Hong Kong. Data are collected from about 1200 horses stabled and trained at the Sha Tin Racecourse. A wide range of variables are included in this dataset e.g. track parameters, environment, training and racing performance, veterinary medical records, and veterinary management. This has provided extensive dataset on racehorse health and performance in a regulated racehorse population environment where all importation and exportation of horses are officially controlled. A wide range of information established in a database in the early 1970s at the HKJC, including records of the health and racing performance of more than 6000 horses, provided an opportunity for a retrospective analysis of the pattern of wastage from retirement and injuries from racing of thoroughbred racehorses at the Hong Kong Jockey Club (Appendix 1).

This study utilised the resources and epidemiology expertise at University of Liverpool and the HKJC to develop strategies which aims to reduce the risk of injury to racehorses during racing and training in Hong Kong.

The following project concept design was considered possible given an environment suitable to extensive and detailed data collection within an integrated framework:

Retrospective analysis of data collected in the past several years was made available. This approach has two broad objectives. The first is to investigate outcomes of interest using data already collected. Outcomes of interest are likely to include (though not be limited to), variables that influence injury, retirement or performance. The second broad objective is to extend the approach to a more general assessment of the usefulness of different data types and different variables and finally an assessment of data collection, collation, analysis and reporting methodology, as well as development of intervention strategy.

Review of systems and objectives for ongoing routine data collection, collation, analysis and reporting. This process could then be extended to design and future development of a clinical Decision Support System (DSS). This approach involves development of a software framework incorporating database, analytical, reporting and expert systems functions (Weber 2007). The system could be designed to accept data from current or future operating database systems developed and maintained by the HKJC. A variety of manual, automated analysis and reporting functions can be integrated into the DSS to allow real time analysis and automated reporting and monitoring of patterns in the data. Performance targets for monitored variables can be used to generate a rule-based diagnostic system (expert-system) that can detect and diagnose possible problems and either indicates corrective measures or diagnostic approaches for further investigation. Major benefits of a DSS include the ability to make real time use of routinely collected data, to detect unanticipated or new problems, and to aid in making effective and efficient decisions in the management of a large and complex operation.

Ongoing studies of risk factors associated with horse health and performance in horses training and racing in Hong Kong can be performed at several levels including large scale, population based studies and tightly focussed, in depth studies on subsets of the data (targeted studies).

Population studies involve collecting more routine data on the racehorse population and applying a variety of analytical techniques to screen the data for patterns and associations. This approach can be used as an initial investigative method for generation of hypotheses about underlying relationships amongst variables. It can also be used for semi- or fully-automated, ongoing monitoring of horse health and performance indices to enable early detection of possible problems in the future.

Targeted studies are designed with specific objectives in mind and generally applied to samples of animals drawn from the population. This approach may involve detailed data collection focussing on particular parameters to investigate issues of interest.

A framework of science-based templates can be drawn on when investigating problems in the future. Incorporating designs for different types of investigations, templates for selecting samples of animals and methodologies for analysis of data collected can be developed in such studies.

A key component of all analyses will be the use of a wide range of analytical techniques including descriptive and univariable analyses as well as complex and advanced, multivariable logistic regression techniques. Multivariable analytical techniques are particularly useful when dealing with complex, multifactorial problems by allowing separation of influences due to multiple risk factors while simultaneously controlling for confounding due to other factors.

The clinical information in the free text veterinary records related to the reasons for the retirement of racehorses provides valuable information for Jockey Club clinicians and managers about the different causes of retirement of racehorses at HKJC. Areas of veterinary interest, for example, tendon injury, osteoarthritis, exercise-induced pulmonary haemorrhage, fractures and non-veterinary reasons for retirement, for example, poor racing ability, old age and compulsory retirement, can be identified. The statistical analysis can facilitate the quantitative analysis of the numerical results obtained from the content analysis. A horse's retirement may result from intrinsic factors, for example, genetic, or extrinsic factors, for example, training or policy changes in the rules for retirement, acting either alone or in combination.

Surveys of the incidence of the reasons for retirement identified in this study are a prerequisite for epidemiological studies (Jeffcott and others 1982, Bourke 1995). The categorised data also support clinical epidemiological research in two ways; first, as a sampling tool, to select a categorised veterinary problem from the existing database, and secondly, as a data collection tool for retrieving certain specific clinical data from the selected category. The approach can then facilitate follow up descriptive study to describe the frequency and pattern of retirements associated with injuries in Thoroughbred racehorses and to compare the characteristics of these horses with those that retired for other reasons. The findings from the descriptive study will provide a useful resource for further case-control studies to investigate risk factors for retirement from racing due to any specific injury of interest. This is the first step toward the development of management tools to reduce the incidence of training and racing injury related retirement in Hong Kong.

Project Objectives

The objectives of this study are:-

1. To use the data which has already been collected to describe the frequency and nature of wastage retirement pattern and categorisation of career ending injuries among the population of Thoroughbred racehorses at the HKJC.
    a. Tendon injury was identified as the single most important veterinary reason for retirement of Thoroughbreds recorded in clinical records at the Hong Kong Jockey Club between 1992 and 2004 (Chapter 2).
    b. This study provides population based data on the frequency, career and economic losses associated with tendon injury induced retirement. This descriptive study has provided a useful resource for further case-control studies to investigate risk factors for retirement from racing due to tendon injury. This is the first step toward the development of management tools to reduce the incidence of tendon injury related retirement in Hong Kong (Chapter 3).

2. To identify the risk factors for these injuries by analysing these data using multivariable statistical models.
    a. Further evaluation of detailed training data (1997-2004) to identify risk factors for retirement because of tendon injuries in Thoroughbred racehorses was undertaken. Conditional logistic regression analyses were performed to identify

risk factors for retirement from racing attributable to tendon injury. Two multivariable conditional logistic regression models were created. In addition to identification of risk factors for tendon injury among racing Thoroughbreds, results have suggested that resources focused on obtaining accurate training data may be misdirected in the absence of internationally agreed criteria for incident tendon injury among racehorses. Nevertheless, changes in training intensity and findings of previous clinical examinations could be used to identify horses at risk of tendon injury-associated retirement (Chapter 4).

3. To reduce the number of horses lost from racing each year by introducing rational intervention strategies to reduce the risk of career ending injuries.
    a. One of the by-products of the investigation on the risk factors for tendon injury associated retirements was the identification of a population of horse which were absent from the race track for protracted periods of time but were not evident on the clinical database as suffering from injury or disease. The impact of the intervention strategy by introduction of the track work and race monitoring system and the "To watch" category was reviewed by assessment of the number of pre-race inspection failures; the number of official veterinary examination (OVE) notices issued and the number of horses in the "To-watch" category (Chapter 5).

4. To develop epidemiological expertise within the HKJC so that the analyses of these data is sustained in future years.

5. To foster links with other internationally recognised centres of excellence in the field of Thoroughbred racing including the network of International Group of Specialist Racing Association of the International Federation of Horseracing Authorities.

6. To develop prospective studies which allow the effect of training on the risk of injuries to be estimated
    a. Key research issues for the Hong Kong racing industry revolve around animal and jockey welfare. This focus is dictated by community concerns over

wastage rates for racehorses, jockey injuries, and injuries and fatalities sustained in training and racing. Although there will inevitably be injury in athletic competition, these losses, associated with voluntary retirement, euthanasia and death could be reduced if risk factors were identified and modified.

b. This thesis concludes with a philosophical view point on the veterinary management of Thoroughbred racing injuries in which a "Think-out-of-the box" concept in assessing the risk of racehorse injuries is discussed. On outcome of this is an integrated technology approach for tracking horse performance recently developed by the Cambridge Design UK in consultation with HKJC. By allowing standardised recording and review of detailed training and biometric data of individual horses this will assist in optimising horse welfare, safety and racing performance (Chapter 6).

Chapter 2

Content Analysis of Free-text Clinical Records Held at The Hong Kong Jockey Club

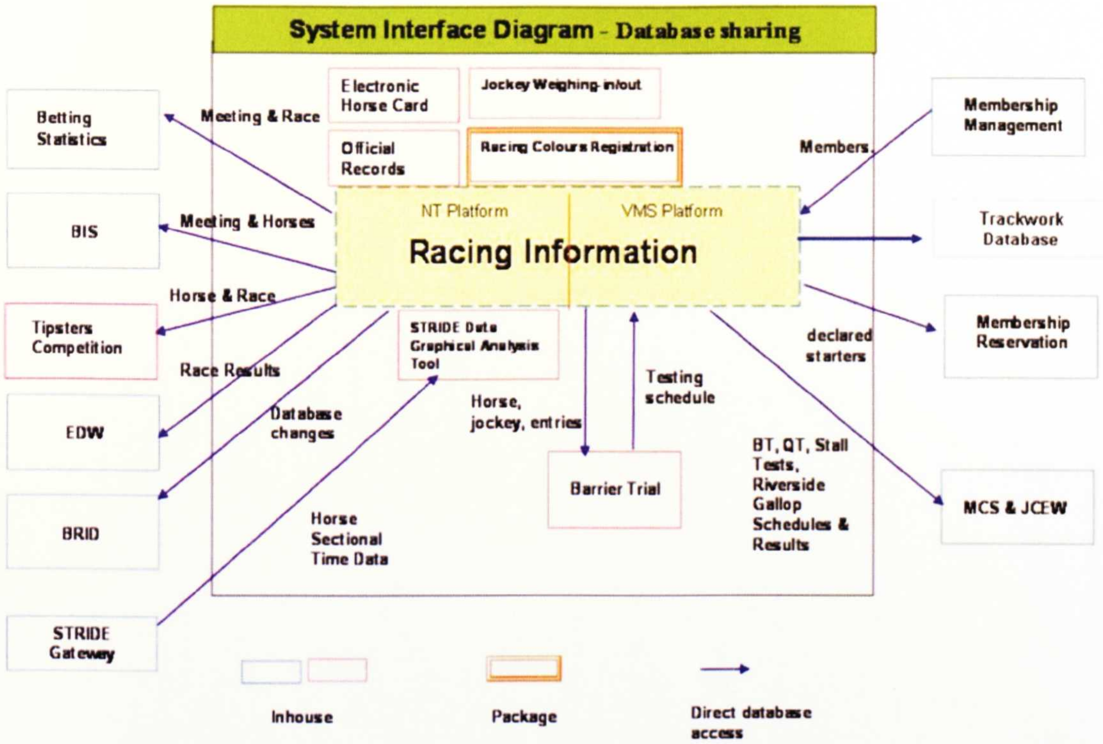
Introduction

Review of the pattern of wastage of racing Thoroughbreds in the racing population in Hong Kong and identification of the most common causes of retirement from racing is the prerequisite starting point for epidemiological studies into the factors affecting racehorse performance and wastage in Hong Kong.

A wide range of information was established in a database in the early 1970s at the Hong Kong Jockey Club, including records of the health and racing performance of more than 6000 horses provided an opportunity for a retrospective analysis of the pattern of injuries and retirement from racing of thoroughbred racehorses at the Hong Kong Jockey Club.

The Racing Information System (RIS) is critical to the Club's business systems (Figure 1). It records and stores details of owners, horses, trainers, jockeys and races data in over 404 Microsoft Access Tables and 3710 data fields including racing records, ownership, trainers and earnings. The oldest records date back to 1972. Data and information are disseminated via system interfaces to both internal and external systems, including a trackwork database.

Figure 1 – An overview information flow diagram of the system interface of the Racing Information System (RIS) of the Hong Kong Jockey Club



Analysis of free text data in clinical records provides useful reference to epidemiologists in planning of analytical studies and for the identification of new research initiatives. This paper describes the methodology used to develop a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of user-defined coding dictionary to examine the free text clinical records kept in the databases of the Hong Kong Jockey Club (Lam et al 2007a).

This was made possible with the use of a content analysis software package- WordStat and SimStat, Provalis Research, Quebec, Canada. This technique enables a large volume of free text records to be sorted in a systematic manner with high accuracy and reliability.

TEXT BOUND CLOSE TO THE SPINE IN THE ORIGINAL THESIS

Use of free text clinical records in identifying syndromes and analysing health data

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The analysis of data in clinical records could be useful to epidemiologists in planning analytical studies and identifying new research initiatives. This paper describes the method used to develop a systematic, replicable technique for compressing many words of text into fewer content categories on the basis of explicit rules of user-defined coding, and systematically sorting a large volume of records accurately and reliably. The method was used to categorise the reasons for retirement from racing in Hong Kong of 3727 thoroughbred racehorses between the 1992/93 and 2003/04 racing seasons into a user-defined dictionary. An automated process successfully categorised 95 per cent of the records. The other 5 per cent were assigned manually to one of the dictionary categories. The whole process from initial screening to the categorisation of all the records took approximately 100 man-hours to complete.

COMPUTERISED medical records are now commonplace in human and animal health (Bass 2001, Hassey and others 2001, Hornof and others 2001, McCurdy 2001, Crowe 2003), and represent a fundamental change in data availability. Centrally maintained and quality-assured databases such as the general practice research database (GPRD), the doctor independent network (DIN) database, and the medicines monitoring unit (MEMO) provide a rich source of data for epidemiological research (Thiru and others 2003). In addition to these standardised databases a number of bespoke and custom-made recording systems have been developed in medical and veterinary practice in the past 20 years.

An important aspect of electronic health recording is the way in which clinical data are captured; coding systems are used to identify clinical signs or specific diseases. In medical systems in the UK, READ, a clinical coding classification system, and OXMIS (Oxford medical information systems) codes are generally used. In other countries the ICPC (international classification of primary care) codes are more widely used. ICD (international classification of diseases) codes act as a reference standard for these primary care coding systems. No such standardisation occurs in veterinary systems.

Coding represents a departure from the use of free unstructured text in paper records and there has been considerable debate over the value of the two methods. Most systems allow for the inclusion of free text but this information is rarely used in any analytical way. Automated methods of analysing free text include natural language processing (NLP) and content analysis. Content analysis is commonly used in the social sciences to classify the content of open questions but is rarely used in veterinary and human medicine. In this paper it has been used for the retrospective analysis of free text clinical records from a clinical database developed by the Hong Kong Jockey Club, to demonstrate its value in the classification of known clinical syndromes, the identification of new problems and improving database design and clinical recording.

With an overwhelming amount of biomedical information available as text, it is normal to ask whether it can be read automatically. Medical language is in essence highly compositional, allowing complex information to be expressed by more elementary components. Embedding the expressive power of medical language into formal systems of representation is recognised as a key step towards sharing such information among systems for medical records, decision support, and information retrieval (Rassinoux and others 1997). For several decades, NLP has been applied in biomedicine to 'read' patient records automatically. Many computer programs, including the Support Vector Machine (SVM) for pattern categorisation, have been designed to extract molecular biological findings from Medline abstracts or full text articles (Dumais 1998). The technique of content analysis enables researchers to examine large volumes of free text with relative ease in a systemic fashion (De Bruijn and Martin 2002).

However, one major contrast between most NLP research in clinical medicine and molecular biology is the type of language material: patient records versus scientific articles. Differences between these two types of text affect the choice of techniques for NLP. Biomedical literature is carefully constructed with few spelling errors and few incomplete phrases. In contrast, clinical language is more colloquial and contains ungrammatical phrases and unstandardised abbreviations. It is more likely to contain segments of 'canned text', that is, longer phrases that are encountered repeatedly in different records. Unknown words in the records, including addresses and spelling errors, present further difficulties in content analysis (Heinze and others 2001, De Bruijn and Martin 2002). A wide-ranging literature review of computer-based patient recording (CPR) over the past decade revealed that the benefits of CPR in terms of clinical information, work output and improvements in administration and financial returns would outweigh these difficulties, provided that health care organisations redesigned certain work processes (Erstad 2003).

A wide range of information established in a database in the early 1970s at the Hong Kong Jockey Club, including records of the health and racing performance of more than 6000 horses provided an opportunity for a retrospective analysis of the pattern of retirement from racing of thoroughbred racehorses at the Hong Kong Jockey Club. This paper describes the method used to extract this information from over 3700 free text clinical records in this database by using the commercial content analysis statistical software package WordStat and SimStat (Provalis Research).

MATERIALS AND METHODS

Study design

A retrospective descriptive analysis of the performance and health records of thoroughbred horses maintained by the Hong Kong Jockey Club was carried out. An analysis of the content of the free text records was used to identify and classify the reasons for the retirement of these horses.

Horses

The Veterinary Department of the Hong Kong Jockey Club has been responsible for the health and welfare of the horses in Hong Kong since the early 1970s. In any year, approximately 1200 racing thoroughbreds are stabled and trained at the Sha Tin Racecourse and there are approximately 600 rid-

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Table 1: Results of the search in WordStat for the number of unique words and phrases in the database of veterinary clinical records of 3727 thoroughbred racehorses

Number of words	Frequency (%)
1	909 (33·4)
2	669 (24·6)
3	536 (19·7)
4	313 (11·5)
5	159 (5·8)
6	90 (3·3)
7	29 (1·1)
8	13 (0·5)
9	3 (0·1)
10	2 (0·1)
Total frequency of words used	2723

TABLE 2: Examples of two-word to 10-word phrases extracted by using WordStat from the veterinary clinical records of 3727 thoroughbred racehorses stating the reasons for retirement

Phrase	Examples	User-defined categories (Table 3 for details)
2-word	Chronic tendonitis	TEN
3-word	Fracture LF cannon	FRC
4-word	Fore fetlock chronic DJD	DJD
5-word	Left fore medial sesamoid fracture	FRC SES
6-word	Age and chronic DJD both fore	AGE DJD
7-word	Partial rupture of left fore medial suspensory	SUS
8-word	Suspensory ligament and chronic DJD both fore fetlock	SUS DJD
9-word	Hold at Shatin Stable pending possible export to Australia	EX
10-word	Hold at Sha Tin Stable pending possible export to UK	EX

LF Left fore

riding school horses, including some retired racehorses, stabled in eight riding schools across the territory.

There are no stud facilities in Hong Kong, and all the horses are imported from overseas, the majority coming from Australia and New Zealand. Approximately 70 per cent of the racing thoroughbreds are imported as unraced two and three-year-olds. They continue to race until they are retired because of declining performance due to age or ill health, when they are assessed for their suitability for the local riding schools, or for export overseas at the owner's request. The import and export of all racehorses is licensed by the Jockey Club, thus maintaining a controlled racing population in Hong Kong.

Recording systems

Computerised data collection started in 1972 and an official Hong Kong Jockey Club Racing Information System (RIS) was established in 1992. At that time, the RIS included records of the interventions carried out by the Veterinary Department, but in 1996 a separate Veterinary System was set up within the RIS to store all health records and prescriptions . The database currently consists of over 3700 fields in the format of over 400 Access (Microsoft) database tables.

Identification and classification of the reasons for retirement by using WordStat content analysis software

The Access database containing the reasons for retirement was imported into the content analysis program WordStat v 4 (Provalis Research) a modular component of the statistical software SimStat V2.5 (Provalis Research). The records detailing the reasons for retirement were analysed by two veterinarians experienced in equine clinical medicine and epidemiology by applying the phrase-finder facility in WordStat. WordStat contains an integral dictionary of words that are excluded from content analysis, for example, articles, adjectives, pronouns, and punctuation, and this dictionary was supplemented by the addition of words from the free text records.

The word frequency and phrase-finder facilities in WordStat were then used to create a dictionary of retirement categories. Information about Jockey Club regulations concerning compulsory and voluntary retirement were incorporated into this process. Under these regulations a horse is compulsorily retired if it has experienced two episodes of epistaxis during or after racing, is in a specified low-rating category or has reached 10 years of age.

After this initial categorisation cross-tabulation and similarity dendrograms were used to identify associations between the categories. Records that had been categorised were removed by transferring them to SimStat. This process of classification was repeated as shown in Fig 1. After five cycles of categorisation and removal, 95 per cent of the records had been classified; the other 5 per cent were classified manually.

RESULTS

In total, 5910 records of individual thoroughbred racehorses were extracted from the RIS system. Before 1992 the reason for retirement was not recorded. Between 1992 and 1995 there were 852 retirements, of which 93 (10·9 per cent) did not include a reason for retirement in their records. From the 1996 season onwards there were no missing records of the reasons for retirement. In total 3727 records from the 1992/93 to 2003/04 racing seasons were included in the study.

Content analysis identified a total of 23,181 words in the free text records and 909 of these (3·9 per cent) were unique individual words. A total of 1814 phrases with two

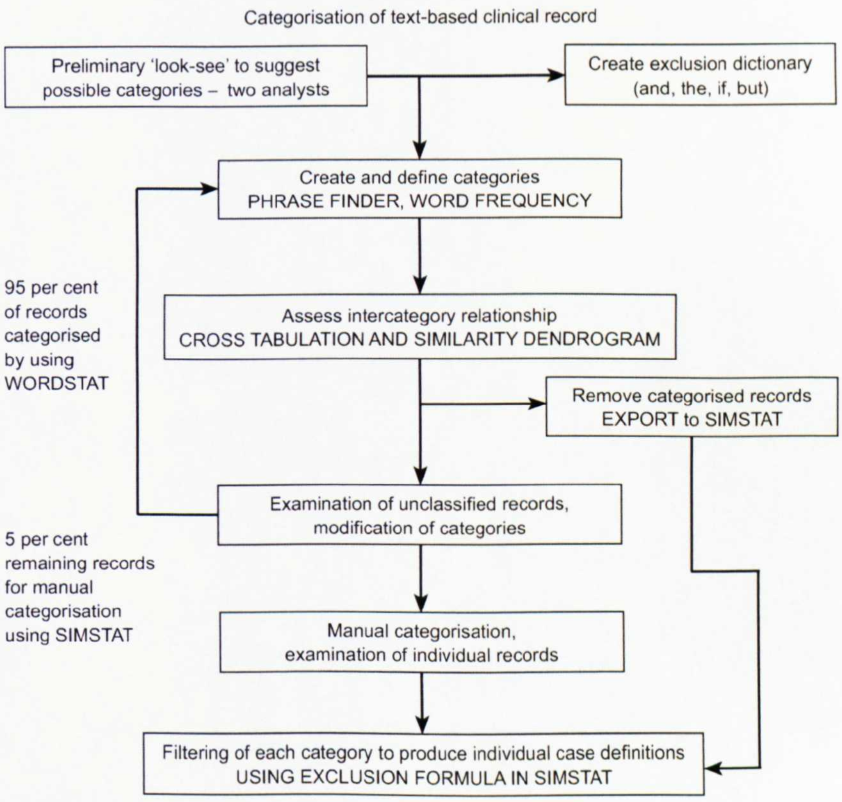

FIG 1: Work flow diagram showing the processing and removal steps in content analysis using WordStat and SimStat software

TABLE 3: Dictionary of 21 user-defined coded categories with definitions created in WordStat

	Category
1	Degenerative joint disease or osteoarthritis (DJD)
2	Tendon or tendon sheath injury (TEN)
3	Suspensory apparatus structure injury including the sesamoidean ligaments (SUS)
4	Fractures of any bone structures (FRC)
5	Sesamoid problems including fractures and sesamoiditis (SES)
6	Forelimb problems including lameness or other unclassified conditions (FLM)
7	Hindlimb problems including lameness or other unclassified conditions (HLM)
8	Heart irregularity (HRT)
9	Colic (CLC)
10	Collapse or inability to rise (CLP)
11	First incidence of bleeding record (FBL)
12	Second incidence of bleeding record which resulted in compulsory retirement (SBL)
13	Behavioural problems (BEH)
14	Poor performance (PER)
15	Low rating and conditions from rules of racing resulting in compulsory retirement (LOW)
16	Old age as reason for voluntary or compulsory retirement (AGE)
17	Laryngeal problem (LYN)
18	Sudden death or severe accidental trauma requiring immediate euthanasia (D)
19	Destination being a riding school post retirement (RS)
20	Destination being exported from Hong Kong post retirement (EX)
21	Miscellaneous retirement reason not specified (for example, voluntary) or clinical condition not listed in the categories or records with no mention of reason for retirement, manual categorisation is required (MIS)

or more words were used on more than one occasion. Their frequency ranged from 669 counts of two-word phrases to two counts of 10-word phrases (Table 1). Examples of the words and phrases contained within the database and identified by the WordStat search engine are shown in Table 2. The first cycle of filtering sorted 2346 (63 per cent) of the records into different categories. After five repeated cycles a dictionary of 21 retirement categories was established and 3564 (95 per cent) of the records were categorised. The other 163 records were assigned manually to one of the categories; they included records of horses with rare clinical conditions or with spelling errors in the text. A dictionary of 21 coded categories, with definitions in WordStat, was created (Table 3).

Cross-tabulation and the dendrogram function in the WordStat software provided information on the distribution of cross-matched cases and clustering among the defined categories. A dendrogram of similarity index (Fig 2) based on Jaccard's coefficient (Jaccard 1901) identified marked clustering between the fracture (FRC) and sesamoid (SES) groups and indicated that there were approximately 50 per cent of cross-matched records having sesamoid fractures. A separate filtering of this fractured sesamoid (FRC + SES) group was carried out by using a filtering formula in SimStat, to confirm the finding and to create a new 'fractured sesamoid' category.

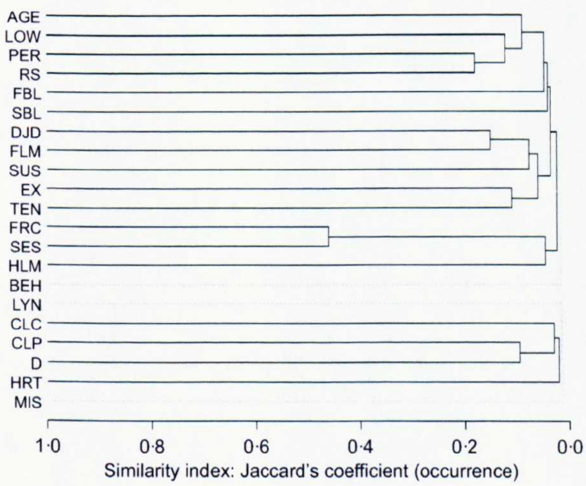

FIG 2: Dendrogram of similarity index based on Jaccard's coefficient illustrating the intercategory relationships in the reasons for retirement

Removing the cross-matched cases from the defined categories in the WordStat dictionary by filtering in SimStat produced a final list of case definitions with a single condition for each category. Fifty-four per cent of the records (2021) included a single veterinary reason for retirement and 1949 (96 per cent) of these were classified into 16 categories (Fig 3). The remaining 73 records were unclassified with rare veterinary diagnoses, for example, stomach ulcers and ataxia. Three hundred and seventeen records (8·5 per cent) appeared in more than one veterinary category, the horses having more than one veterinary problem specified as the reason for their retirement, for example, degenerative joint disease and tendon injury. There were 1389 records (37·3 per cent) with no veterinary reason for retirement, and 93 records (2·5 per cent) had nothing recorded as a reason for retirement. The destinations after retirement, for example, riding school or country of export, were the only data in 270 records (7 per cent). The remaining 1026 records were classified into one of five categories: poor performance (380); low performance rating resulting in compulsory retirement (309); voluntary or compulsory retirement due to old age (256); behavioural problems (33); and miscellaneous reasons such as the death of the owner or financial problems (48). Further manual subclassification of the 107 non-proximal sesamoid fractures showed that 43 (40 per cent) were carpal fractures, 19 (18 per cent) were third metacarpal fractures and nine (8 per cent) were pelvic fractures; the remaining 34 per cent involved 14 other anatomical structures. The whole process, including the initial screening of the clinical text records, the creation of categories with definition and context analysis, was completed in approximately two weeks.

DISCUSSION

Content analysis is a systematic, replicable technique for compressing many words of text into fewer categories, on the basis of explicit rules of coding, which enables a large volume of free text clinical records to be sorted in a systematic manner (Heinze and others 2001). This paper demonstrates its epidemiological potential in classifying free text clinical records. Over 95 per cent of the 3727 records in a health database were categorised by the use of automated content analysis and a user-defined dictionary of categories.

The most critical and difficult task in this process was the initial definition of the categories. A knowledge of the database, the target population and the clinical domain were important in screening the database to define these categories. Their definition was facilitated by the automated generation of frequency lists of words and phrases so that differences in word usage could be identified, and by the freedom to construct a user-defined dictionary. These procedures resolved ambiguities in the categorisation of the records and made it possible to include spelling errors and compound words. WordStat and SimStat provide a user-friendly combination of programs for content and statistical analysis respectively. The combination is easy to import and it provides adequate support for conversions from most common formats, for example, Excel, MS Access and SPSS. The Drag & Drop Dictionary Editor function makes it easy to create categories and provides flexibility in the creation and management of the dictionary of categories. Easy navigation between the WordStat and SimStat modules makes the repeated filtering process a convenient task for both automated categorisation and manual coding. The Keyword-In-Context function made it possible to check the accuracy of the user-defined dictionary of categories after each passage of automated filtering by selecting and identifying the context of a word or phrase within the original record. These automated procedures, based on explicitly formulated and unambiguous logical conditions,

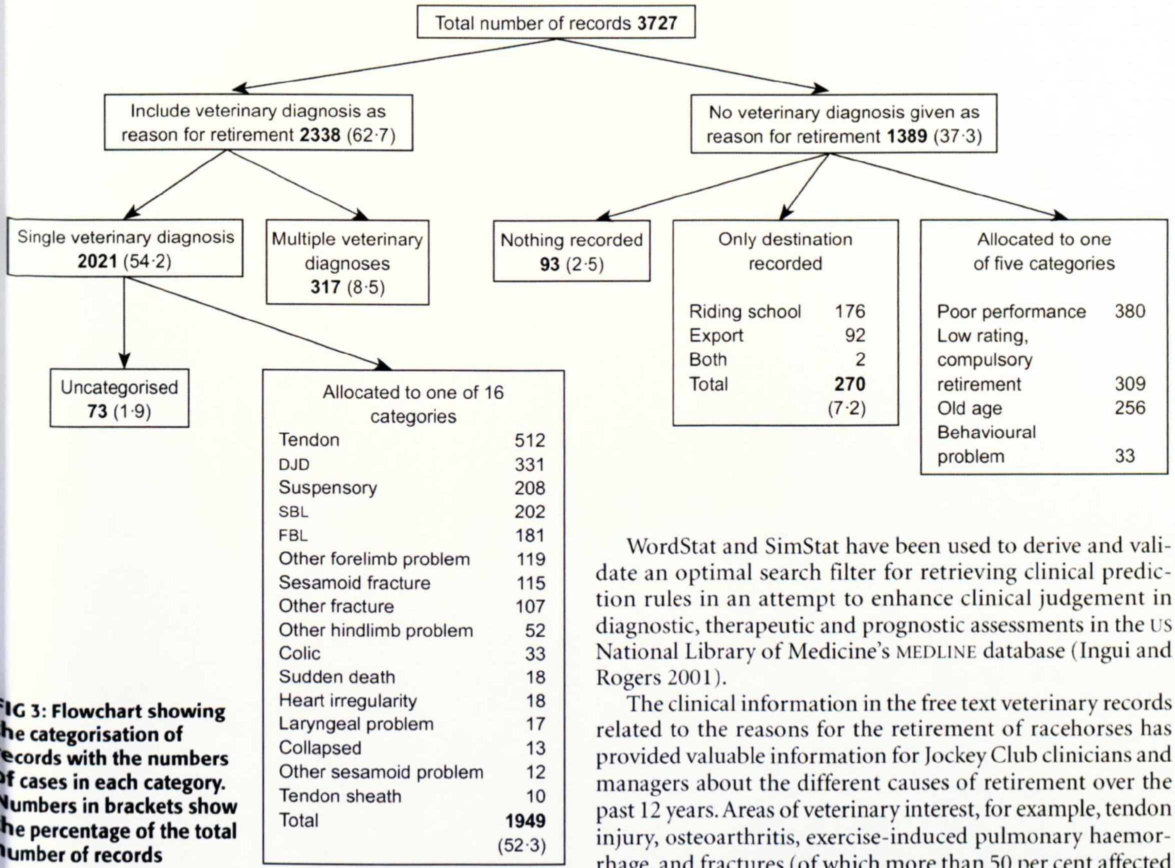

FIG 3: Flowchart showing the categorisation of records with the numbers of cases in each category. Numbers in brackets show the percentage of the total number of records

exclude intersubject variance and are faster than manual coding. Nevertheless, all the records in each final filtered category were screened manually to finalise the classification of the records, so that the automated process could be validated and new combined categories could be created with reference to the dendrogram similarity index.

The text-mining approach using WordStat has proved to be useful in the analysis of the content of clinical narrative in the veterinary records. Textual analysis has been used extensively to study information such as journal articles, open-ended questions and interviews, in addition to free text medical records (Heinze and others 2001). However, scientific articles and abstracts from biomedical research databases are different from free text narrative clinical records. Biomedical literature is carefully constructed and carefully proofread, so that spelling errors and incomplete phrases are less of a problem. Clinical narratives, like those in this study, are generally more colloquial and use ungrammatical constructions and unstandardised abbreviations (De Bruijn and Martin 2002).

Providing terminology that is standardised and understood by all clinicians has been a major problem in medical informatics. International medical classification schemes such as the Systematized Nomenclature of Medicine, SNOMED International (Lussier and others 1998) and Unified Medical Language System, UMLS (McCray and others 1993), have resulted in the construction of clinical lexicons to support the entry of structured data into patients' records (Warren and others 1998). The user-defined dictionary of categories developed in WordStat provides a mechanism for the development of a structured lexicon for veterinary clinical records, and is an important practical tool for clinical use and research. The flexibility of construction of a user-defined dictionary in WordStat, in combination with SNOMED, has great potential for categorising human and veterinary clinical records simultaneously, for example, in the investigation of zoonotic disease.

WordStat and SimStat have been used to derive and validate an optimal search filter for retrieving clinical prediction rules in an attempt to enhance clinical judgement in diagnostic, therapeutic and prognostic assessments in the US National Library of Medicine's MEDLINE database (Ingui and Rogers 2001).

The clinical information in the free text veterinary records related to the reasons for the retirement of racehorses has provided valuable information for Jockey Club clinicians and managers about the different causes of retirement over the past 12 years. Areas of veterinary interest, for example, tendon injury, osteoarthritis, exercise-induced pulmonary haemorrhage, and fractures (of which more than 50 per cent affected the proximal sesamoid bones), and non-veterinary reasons for retirement, for example, poor racing ability, old age and compulsory retirement, have been identified. The statistical analysis function of WordStat and SimStat can facilitate the quantitative analysis of the numerical results obtained from the content analysis.

A horse's retirement may result from intrinsic factors, for example, genetic, or extrinsic factors, for example, training or policy changes in the rules for retirement, acting either alone or in combination. Surveys of the incidence of the reasons for retirement identified in this study are a prerequisite for epidemiological studies (Jeffcott and others 1982, Bourke 1995). The categorised data also support clinical epidemiological research in two ways; first, as a sampling tool, to select a categorised veterinary problem from the existing database, and secondly, as a data collection tool for retrieving certain specific clinical data from the selected category.

Individual clinicians have different styles for recording data, and it is therefore necessary to design a standardised format for the recording and categorisation of the common veterinary diagnoses in racing thoroughbreds in Hong Kong. A structured input of clinical data by categories together with free text descriptions, could support the development of a computerised system to follow the changing patterns of veterinary problems over time. Timely data analysis could then help in making clinical decisions and introducing suitable treatments for racing injuries and other diseases, and in assessing their success.

Extensive surveys have been carried out in Europe to examine the validity and reliability of computerised medical records (Grimsmo and others 2001, Hassey and others 2001, Thiru and others 2003). The major obstacle to extracting more epidemiological data from computerised medical records is caused by the information in the databases not being uniquely linked to episodes of care (Grimsmo and others 2001). The content analysis technique described in this paper can facilitate the retrospective identification of changing patterns of disease by making use of previously cumbersome free text clinical records. In addition, medical language will be preserved without the need to resort to coding when the data are recorded, so facilitating the identification of emerging diseases or new patterns of disease.

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Discussion

The text-mining approach using WordStat described in this study has proved to be a useful sampling and data categorisation tool in the content analysis of clinical narrative in the veterinary records. The reasons for retirement from racing in Hong Kong for 3727 Thoroughbred racehorses, between the 1992/93 and 2003/04 racing seasons, were categorized into a user-defined dictionary. The most critical and difficult task in this process was the initial definition of the categories. Knowledge of the database in data collection, target population and clinical domain were important in screening the database to define these categories.

In addition, the technique of categorization using WordStat facilitated future standardization of data entry in the veterinary records at the Hong Kong Jockey Club. The user-defined dictionary which allows expansion and modification of categorisation is also applicable for analysis of other free text veterinary records including reasons for issuance of official veterinary examinations due to training or racing injuries or other health reasons (for example, EIPH). Inter-category relationship can be easily assessed by the dendrogram function of similarity index to identify clustering effect of cross-matched case occurrence among different categories. This technique enables effective filtering of records that have two or more related categories of interests for further evaluation and new precise combination category can then be created.

Since documentation styles vary among individual clinicians, the outcome of the study has effected change of management to include precise key word category incorporated in the proposective entry of veterinary records for reasons of retirements as well as in official veterinary examination records. This has added value to structure a standardized input format for ease of recording and specific defined categorization of common veterinary diagnoses in racing Thoroughbreds in Hong Kong.

The software also has a wide application for use in inter-disciplinary investigation such as the assessment of clinical syndromes including lameness and disease surveillance, for example, fever cases, where veterinary clinical records can be interrogated by user-defined categories. Sophisticated thesauri can also be developed using content analysis on any text records. A structured clinical data input by categorization alongside free-text descriptions in all the veterinary clinical records allows effective monitoring of the ever-changing patterns of veterinary issues of interest over time. Timely data analysis can then provide management decision support in implementing intervention strategies and follow-up assessment in the surveillance of racing injuries and equine disease.

The clinical information related to the reasons for retirement of racehorses in the free-text veterinary records has provided valuable information for both Jockey Club clinicians and managers to understand the pattern of different causes of retirement over the past 12 years. Areas of veterinary interest (tendon injury; osteoarthritis; exercised induced pulmonary haemorrhage; and fractures of which greater than 50% affected the proximal sesamoid bones) and non-veterinary reasons for retirement (poor racing ability; old age and compulsory retirement) have been identified in this study. The findings enable prioritization of focus of research on tendon injury related retirement for further descriptive analysis and investigation of risk factors for affecting the career ending injury.

CHAPTER 3

Descriptive analysis of retirement of Thoroughbred racehorses due to tendon injuries in Hong Kong (1992 to 2004)

Introduction

Tendon injury has been identified as the single most important veterinary reason for retirement of Thoroughbreds recorded in clinical records at the Hong Kong Jockey Club (Chapter 2).

This paper details a descriptive analysis of retirement of Thoroughbred racehorses associated with superficial digital flexor tendon injuries and comparison of their characteristics with the remaining population of horses retired for other reasons can provide population based data on the frequency, career and economic losses associated with tendon injury retirement (Lam et al 2007b). The useful resources of findings from the descriptive analysis can enable further case-control studies to investigate risk factors for retirement from racing due to tendon injury as a first step toward the development of management tools to monitor the incidence of injury related retirement in Hong Kong.

However methodology of statistical analysis of census data has to be considered in a study of the whole population. Epidemiology is the study of the frequency, distribution and determinants of disease and health (in veterinary terms of productivity and welfare) in populations. In any epidemiological study one has to define the population for which one wants to find out frequency, distribution or determinants. This is commonly known as the target population. One can define this population as for each specific study. Often it defines itself, as in this study, the racehorse population in Hong Kong. The definition of the population is often defined by the question. By using statistical methods one can arrive at estimates of the frequency, distribution and determinants within certain confidence limits with a known degree of accuracy. This is achieved by randomly selecting a study or sample population. By using statistical sampling one can generalise from the study population to the target population. One cannot generalise from the study population to all the populations in the world. It would be inappropriate to suggest that the frequency of injury in racehorses in Hong Kong can be made reference to that in trotting horses in United States. Similarly it is already known that the distribution of training and racing injuries in Hong Kong is different to those in the United Kingdom. It appears not to be applicable to generalise between these populations. One might use analogy but this is not statistical generalisation.

In the case of an example of the sample of a target population with a frequency estimate of 36% with 95% confidence intervals of 25 to 45%, it states that the frequency in the study or sample population is 36%. In reference to generalisation to the whole population one would be 95% confident that the true value in the target population is somewhere between 25 and 45%. However this cannot be generalised to a completely different population.

In this descriptive analysis of tendon injury related retirement, a census of the target or whole population but not a sample was studied. The retirement rate applies to the true retirement rate of the whole population. No generalisation to the whole population is required as it already refers to all the data from that whole population. It appears not to be appropriate to apply this data statistically to other populations. The target population is defined as Hong Kong racehorses. In this case no statistical tests were conducted in the study.

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Descriptive analysis of retirement of Thoroughbred racehorses due to tendon injuries at the Hong Kong Jockey Club (1992–2004)

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Keywords: horse; Thoroughbred; racehorses; retirement; tendon injury; descriptive analysis; Hong Kong Jockey Club

Summary

Reasons for performing study: **This study was part of a programme to optimise the longevity and maximise the health and welfare of the Thoroughbred racehorses in Hong Kong. Injuries to the superficial digital flexor (SDF) tendon are the most common veterinary reason for premature retirement in this population.**

Objective: **To describe the frequency and pattern of retirements associated with SDF tendon injuries in Thoroughbred racehorses and to compare the characteristics of these horses with those that retired for other reasons.**

Methods: **A retrospective analysis of retirement records documented in the Hong Kong Jockey Club clinical database between 1992 and 2004 was conducted. As this is complete census data, no statistical inference to the population is necessary.**

Results: **The mean annual cumulative incidence of retirements due to tendon injury was 3.2% accounting for 14% of all retirements. The risk of tendon injury increased over the 12 year period from 2.3–4.2%. The racing career, number of starts and earnings of horses retired with tendon injuries were reduced by 25.6, 41.2 and 53.3%, respectively. Thirteen percent of these horses never raced in Hong Kong. A greater proportion of 3- and 4-year-olds and entire males were retired because of tendon injuries. Ninety-seven percent of injuries affected the forelimb, the right more frequently than the left. Only 19.7% of retired horses that had received ultrasound examination for SDF tendon injury retired for this reason.**

Conclusions: **This study provides population based data on the frequency, career and economic losses associated with tendon injury induced retirement.**

Potential relevance: **This descriptive study has provided a useful resource for further case-control studies to investigate risk factors for retirement from racing due to tendon injury. This is the first step toward the development of management tools to reduce the incidence of tendon injury related retirement in Hong Kong.**

Introduction

Tendon injury was the single most important veterinary reason for retirement of Thoroughbreds recorded in clinical records at the Hong Kong Jockey Club 1992–2004 (Lam *et al.* 2007). Injuries of the superficial digital flexor (SDF) tendon are acknowledged to be common in Thoroughbred racehorses but there are few precise data on their frequency in training and racing owing to the lack of population based descriptive studies.

Published reports use different denominators, horse populations and case definitions. The prevalence of tendon injuries during racing on US racetracks was estimated as less than 2 per 1000 race starts (Peloso *et al.* 1994). In the UK, Williams *et al.* (2001), reported 0.78 tendon or suspensory ligament injuries per 1000 starts. In an early study on 'wastage' of racehorses during training in the UK by Rossdale *et al.* (1985), the prevalence of diagnosed tendon injuries was reported to be 3.4% (20/581). In a retrospective study in Japan, the overall prevalence of SDF tendon injuries sustained by flat racing Thoroughbreds, in both training and racing, was 11.1% (1130/10,262 horses) (Kasashima *et al.* 2004).

A number of risk factors for tendon injuries have been identified. These include horse-related factors, such as age, sex, weight, previous steeplechase experience and tendon abnormalities detected at pre-race inspection; and course-related factors such as racecourse, surface and distance (Mohammed *et al.* 1991, 1992; Cohen *et al.* 1997; Takahashi *et al.* 2004; Perkins *et al.* 2005).

Treatment for SDF injury is often prolonged with a high prevalence of re-injury (Palmer *et al.* 1994; Gibson *et al.* 1997; Dyson 2004), therefore, prevention through rational intervention strategies is particularly important to improve horse welfare and longevity of racing career. This is the aim of a study currently being carried out at the Hong Kong Jockey Club (HKJC). Here we describe the early retirement of Thoroughbred racehorses associated with SDF tendon injuries; and compare their characteristics with the remaining population of horses retired for other reasons.

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Materials and methods

Study population

All Thoroughbred racehorses stabled at the HKJC, between 1 July 1992 and 30 June 2004, were included in this study. There are no stud facilities in Hong Kong, therefore all racehorses are imported, the majority (approximately 70%) from Australia and New Zealand. Most (approximately 70%) are imported as unraced 2- and 3-year-olds and race until age, performance or health-related retirement. During the period of study the median number of horses imported per annum was 336 (range 232–458).

Horse racing in Hong Kong consists entirely of flat racing. The season year runs from 1st July to 30th June the following year, with races taking place from late August or early September through to the end of June. There is continual importation and retirement of racehorses throughout the season. The majority of the races (approximately 87%) are held on the sand based turf tracks at the Happy Valley Racecourse in the heart of Hong Kong city, and at the Sha Tin Racecourse in the New Territories. Sha Tin also has an all-weather 'dirt' track on which approximately 13% of races, and most of the training, occur. All racing and training on the main all-weather track and turf tracks is in a clockwise direction. A smaller all-weather track is available for trotting and canter work on which training in an anti-clockwise direction is available one day a week.

All racehorses are stabled at Sha Tin Racecourse. A maximum of 1200 horses can be accommodated at any one time. All clinical care is provided by a team of veterinary surgeons employed by the HKJC. Details of the training facilities and procedures of veterinary inspections to manage the suitability of horses to race have been described previously (Osborne *et al.* 2000; Stewart and Watkins 2004).

Horses can potentially remain in training and racing until compulsory age-related retirement at age 10 years. This age limit was 11 years prior to the 1996 season. Premature compulsory retirement may also occur. Current regulations require compulsory retirement following 2 officially recorded episodes of epistaxis (external exercise induced pulmonary haemorrhage, EIPH) or 2 episodes of heart irregularity during the racing career. Horses can be retired voluntarily at any time during the racing career due to injuries with a poor prognosis or for other reasons. Retired racehorses are assessed by a compulsory veterinary inspection for suitability for local riding schools, for export or when an application is made for a replacement horse. All import and export of racehorses is licensed by the Jockey Club. This policy maintains a controlled racing population in Hong Kong.

Design and HKJC database

A retrospective study was conducted using data from computerised records held by the HKJC.

The HKJC began computerised data collection in 1972. In 1992, an official Racing Information System (RIS) was established, followed, in 1996, by a separate Veterinary System within the RIS, to store all veterinary clinical records and prescriptions. The database currently consists of over 3700 fields in over 400 Access (Microsoft) database tables. Data on date and reasons for retirement and other related variables e.g. racing history, horse and owner details were available for the 12 years, 1992–2004.

Data analysis

Reasons for retirement were recorded in the database as free text. These entries were classified using content analysis software (WordStat version 4)[1]. This has been reported in detail elsewhere (Lam *et al.* 2007). Descriptive analyses were performed with Epi-info, Version 3.3.2, Centers for Disease Control and Prevention (CDC), USA, (Dean *et al.* 2005) to produce population estimates of parameters associated with retirement from racing due to tendon injury in Hong Kong, between 1992 and 2004.

Results

The number of horses in the racing population in each race season, including all new imports and retired horses increased over the study period from 1045 to 1432, median 1286 horses (Table 1). A total of 3727 records of retired racehorses were available for analysis and fourteen percent (510/3727) of these were due to SDF tendon injury. The mean annual cumulative incidence of retirements due to tendon injury was 3.2%.

The cumulative incidence of all retirements increased from 18.5% (193/1045) to 28.8% (412/1432) and the tendon injury-related retirements from 2.3% (24/1045) to 4.2% (60/1432) (Table 1). The temporal pattern revealed an increase in the annual cumulative incidence of all retirements with the major increase in the risk of retirement occurring between 1994 and 1998 (Fig 1). In

TABLE 1: Summary of the number of horses in training and number of retirements in each season between 1992–93 and 2003–04

Racing season	Horses (n)	Horses retired (cumulative incidence)	Horses retired from tendon injuries (n)	Percentage retirement attributed to tendon injuries	Annual cumulative incidence of retirement due to tendon injury
1992	1045	193 (18.5)	24	12.4 (24/193)	2.3 (24/1045)
1993	1098	217 (19.8)	31	14.3 (31/217)	2.8 (31/1098)
1994	1110	200 (18.0)	34	17.0 (34/200)	3.1 (34/1110)
1995	1195	242 (20.3)	41	16.9 (41/242)	3.4 (41/1195)
1996	1298	312 (24.0)	43	13.8 (43/312)	3.3 (43/1298)
1997	1299	319 (24.6)	39	12.2 (39/319)	3.0 (39/1299)
1998	1274	348 (27.3)	55	15.8 (55/348)	4.3 (55/1274)
1999	1271	338 (26.6)	40	11.8 (40/338)	3.1 (40/1271)
2000	1331	353 (26.5)	48	13.6 (48/353)	3.6 (48/1331)
2001	1437	394 (27.4)	42	10.7 (42/394)	2.9 (42/1437)
2002	1421	399 (28.1)	53	13.3 (53/399)	3.7 (53/1421)
2003	1432	412 (28.8)	60	14.6 (60/412)	4.2 (60/1432)

TABLE 2: Prevalence of retirement stratified by age, gender, race history before and after importation to Hong Kong for the 510 horses that retired due to tendon injuries and the 3217 horses that retired for other reasons

	Category	Retired with tendon injuries (Total 510)	Retired with other reasons (Total 3217)	Prevalence of tendon injuries in the retired population (%) (Mean 13.68%; 510/3727)
Age (years)	2	2	34	5.56
	3	78	318	19.70
	4	119	575	17.15
	≥5	311	2290	11.96
Gender	Gelding	471	3034	13.44
	Entire male	36	159	18.46
	Female	3	24	11.11
Race career before import to Hong Kong	Never raced before import	335	2185	13.29
	Raced before import	175	1032	14.50
Race career in Hong Kong	Never raced	68	177	27.76
	Raced at least once	442	3040	12.69

contrast, the proportion of all retirements due to tendon injury fluctuated within a narrow range over the whole study period (10.7% in 2001–17% in 1994) and increased from 12.4% in 1992 to 14.6% in 2003 (Figure 1).

Age and gender distribution

There were a higher proportion of horses retiring due to tendon injuries at ages 3 and 4 years (19.7% and 17.2% respectively) than at 2 (5.6%) or >5 (12.0%) years (Table 2). A higher proportion of entire males retired with tendon injuries (18.5%) compared with geldings (13.4%) and females (11.1%), as shown in Table 2.

Training period from import to retirement in Hong Kong

Horses that were retired because of tendon injuries were younger and in training in Hong Kong for a shorter time compared with the remaining retired population. The median age at retirement from tendon injuries was 5 years (range 2–11) compared with 6 years (range 2–11) for the remaining retired population. The median time period in training was 29 months (range 2–104) for the horses that retired due to tendon injury.

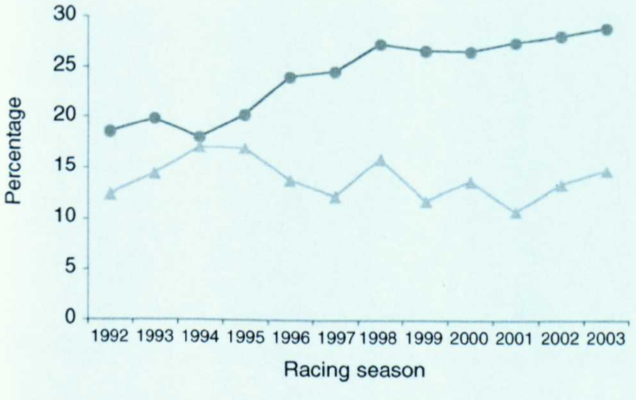

Fig 1: Annual cumulative incidence of all retirements from racing at the HKJC and the percentage of retired horses attributed to tendon injuries, in each racing season (1992–2003). ● = Annual cumulative incidence of all retirements. ▲ = Percentage of retired horses attributed to tendon injuries.

This was over 25% less than the median time in training of 39 months (range 0–106) in the population that was retired for other reasons.

Career earnings in Hong Kong

Career earnings in the group retired because of tendon injuries (median = Hong Kong Dollars (HK$) 0.35 million: range HK$ 0–8 million) were less than half of those in the remaining retired population (HK$ 0.75 million: range HK$ 0–35 million). Almost one-third of the horses that retired from tendon injuries (28.4%; 145/510 horses) had no earnings in their career. This was greater than the remainder of the retired population, where 18.5% (596/3217) had no career earnings.

Race history and career starts in Hong Kong

Horses that retired from tendon injuries had fewer race starts than the remaining retired population. The median number of starts was 10 (range 0–68 starts) and 17 (range 0–107 starts), respectively. In both populations the percentage of horses that had not raced before importation was similar, being 65.7%; (335/ 510) in horses that retired from tendon injuries and 67.9% (2185/3217) in the remaining retired population (Table 2). Overall 245 retired horses (6.6%) never raced in HK. The percentage of horses retiring with tendon injuries that did not race in HK (13.3%; 68/510) were over twice that recorded in the population that retired for other reasons (5.5%; 177/3217).

TABLE 3: Distribution of affected leg(s) in the 510 horses that retired due to tendon injury

	Number of horses (column %)			
Affected leg	All horses	Geldings	Entire males	Females
Left-fore	164 (32.2)	148 (31.4)	14 (38.8)	2 (66.7)
Right-fore	287 (56.3)	266 (56.5)	20 (55.6)	1 (33.3)
Both forelegs	44 (8.6)	42 (8.9)	2 (5.6)	0
Left hind	6 (1.1)	6 (1.3)	0	0
Right hind	9 (1.8)	9 (1.9)	0	0
TOTAL	510	471	36	3

Distribution of limbs affected

Over 97% of the tendon injury induced retirements were associated with the forelimbs. Right-fore SDF tendon injuries were more common than left-fore SDF tendon injuries and 8.6% (44/510) of horses had injured tendons in both forelimbs (Table 3). There were only 9 cases (1.8%) reported in the right hind tendon and 6 cases (1.1%) in the left hind tendon.

Ultrasound examination of the superficial digital flexor tendon

There was a 4-fold increase in the number of ultrasound examinations of tendons performed over the 12-year period of study, from 43 in the 1992 to 172 in 2004. A total of 824 horses underwent tendon ultrasonographic examination, of any limb prior to the date of retirement, of which 162 (19.7%) retired due to tendon injury. Thirty-two percent (162/510) of horses retiring from tendon injuries had an ultrasonographic examination of the SDF tendons, during their career in Hong Kong, of which 98% (158/162) underwent examination of the tendon recorded as injured at the date of retirement. Twenty-one percent (662/3217) of horses that retired for other reasons also had a history of ultrasonographic examination of SDF tendons.

Discussion

A number of studies have highlighted the importance of tendon injuries to Thoroughbred horses but few have provided population based data on the quantitative contribution of this injury to racehorse longevity and performance. The structure of racehorse management in Hong Kong offers the opportunity to do this and to identify important risk factors for tendon injury. Although the primary purpose of this study was to improve the health of the racehorse population in Hong Kong it could also be of relevance to the Thoroughbred population worldwide. Over a 12-year period tendon injury was the single most common veterinary related reason for retirement, with a median of 13.7% of all retirements being due to tendon injury.

The temporal trend was interesting as there was a relatively small variation in the annual percentage of retirements that were attributed to tendon injury, despite an increase of approximately 2-fold in the annual cumulative incidence of horses that retired from tendon injuries. This may be explained by an increase in the cumulative incidence of all retirements from 18.5% to 28.8% and by changes in HKJC's policies. From 1995 new criteria for the replacement of racehorses were introduced which made it easier to retire a horse for nonveterinary reasons. This might be expected to increase the total proportion of retirements and the number of these attributed to nonveterinary reasons. Intuitively, this should result in a decrease in the proportion of retirements attributed to tendon injury but this was not evident because of the independent increase in the cumulative incidence of 'tendon injury retirements'.

The data used for this study were taken from historical retirement records. Veterinary examination is compulsory at retirement and the reason for retirement must be listed. Previous analysis of these data indicated good compliance with less than 2.5% of retirements being unclassified (Lam *et al.* 2007). The annual cumulative incidence of tendon injury retirements ranged 2.3–4.3%. This is lower than the prevalence of SDF tendon injury reported from Japan in 1999 of 11% (Kasashima *et al.* 2004). There may be differences in training regimens, training surfaces and population demographics that contribute to differences between racing populations. However, our data suggest the most likely explanation is the difference in case definition: In this study only those tendon injuries that resulted in retirement are included, whereas the Japan study focussed on the first incidence of ultrasound diagnosed tendon injuries occurring during training and racing (Kasashima *et al.* 2004). The overall frequency of ultrasonographic examination for suspected tendon injury in our retiring population was 22% (824/3727), but only 19.7% (162/824) of these retired because of SDF injury. This suggests that the majority of horses with acute tendon injuries may recover and continue an active athletic life eventually retiring for other reasons.

The age distribution of horses retired because of a tendon injury was different to that reported by Kasashima *et al.* (2004). In the current study, it was highest in the 3-year-old group and appeared to decrease with age. The higher prevalence rates of retirement from tendon injuries in the 3- and 4-year-old groups could reflect extrinsic risk factors, such as increasing exercise or racing intensity or intrinsic risk factors such as genetic susceptibility. It is also possible that horses age >5 years might have been better managed to have a longer racing career despite tendon injury at an early age. The reduced rate of retirement in 2-year-old horses is probably because they have not accumulated sufficient exercise related microdamage to result in tendon injury (Birch *et al.* 1999; Smith *et al.* 1999). It may, however, also be the case that the apparent reduction in the proportion of horses retiring due to tendon injury in both young and old horses is due to an increase in the number of retirements for other reasons. For example, fractures are particularly common in horses in their first year of training (Parkin *et al.* 2004) and retirement due to poor performance is likely to be more common in older horses, as well as young horses showing little racing potential early in their career.

The horse population at the HKJC consists predominantly of castrated males and this is reflected in the retirement data where 94% (3505/3727) were geldings. The proportion of retirement attributed to tendon injuries appeared to be slightly higher in the entire males (18%; 36/195) than in geldings (13.4%; 471/3505). The reason and significance of this is unclear. However, Kasashima *et al.* (2004) also demonstrated an increased likelihood of SDF tendon injury in entire males and Perkins *et al.* (2005) reported that male horses were more likely to sustain tendon injuries during training and racing. The effect of male sex hormones associated with the often difficult temperament of entire horses may increase the likelihood of tendon injury. Alternatively, differences in body composition, including greater forequarter size, have been reported in entire males of other species compared to geldings (Watson 1969; Wood *et al.* 1986). Similar differences in entire horses may increase the likelihood of SDF tendon injury.

Premature retirement is important to the HKJC. It affects the ability of race-goers to follow the form of individual horses, investment from the horse owners and the HKJC, and, more importantly, animal welfare. This study provides quantitative data on the effect of early retirement because of tendon injury compared with all other reasons for retirement; and demonstrates the economic and welfare impact of tendon injury retirements in the population of racehorses at the HKJC. Their racing career was reduced by a median time period of 1 year, the median period in training decreased by 25.6%; starts were reduced by 41.2% and earnings by 53.3%. There were also a significant proportion of horses that retired due to tendon injury (13.3%: 68/510) that had never raced in Hong Kong. This did not appear to reflect events occurring prior to their importation into Hong Kong, as there was little difference in the tendon retirement rate for those horses imported as unraced, compared with those that had raced prior to importation. It is possible that this reflects events occurring during the preparation for racing while in Hong Kong. Perkins *et al.* (2005) also found that injuries to the SDF tendons were common in Thoroughbreds in preparations without a race start. The consistency of these findings suggests that the early phases of training are high-risk periods for development of SDF tendon injury. Modifications to early training regimens could, therefore, significantly reduce the number of horses retiring due to tendon injury.

SDF tendon injuries, which resulted in retirement, were more common in forelimbs than hindlimbs. This finding was consistent with other studies (Peloso *et al.* 1994; Cohen *et al.* 1997; Kasashima *et al.* 2004; Takahashi *et al.* 2004; Perkins *et al.* 2005). In the current study the risk of retirement from tendon injuries in the right-fore leg appeared to be 1.75 times higher than the left-fore leg. The predominant direction of racing and training in Hong Kong is clockwise. Tendon injuries in horses that raced and trained in the anticlockwise direction are more common in the left (47/63) compared with the right-fore leg (17/63) (Rooney and Genovese 1981). This suggests that tendons of the inside forelimb are at greater risk on oval tracks. The inside limb is most commonly used as the lead leg (the forelimb that reaches out the furthest and is the only limb in contact with the surface immediately before the suspension phase) on these tracks (Parkin *et al.* 2006). This increased risk may reflect more than simple loading, as ground reaction force is greater in the nonlead limb at the canter and has been predicted to be similar at higher speeds (McGuigan and Wilson 2003; Witte *et al.* 2004).

Clinical diagnosis of tendon injuries at the time of retirement was confirmed by a combination of clinical examination, ultrasonographic examination or *post mortem* examination. The low percentage of records of ultrasonographic examination in the retired group from SDF tendon injuries (32%; 162/510) reflects, in part, the development and increased use of this technique during the study period. It is also possible that some horses were not presented for ultrasonographic examination by their trainers. This may be partially attributed to the HKJC regulations, which require an official veterinary examination following diagnosis of injuries. Horses that have undergone an ultrasound examination for diagnosis of tendon injuries must pass an official veterinary examination before and after a gallop, before they are allowed to enter to race. A list of such horses is published and horse owners are notified. It is also possible that trainers use their own expertise to rehabilitate mild tendon injuries and see no great advantage in ultrasonography. If this is the case, there may be some value in collecting and formalising these skills and the knowledge behind them. These horses were probably treated conservatively and kept in training until retirement. It is unlikely that the majority of tendon injuries were due to single overstrain events that would not have been presented for ultrasound examination prior to the injury that resulted in retirement (Dowling and Dart 2005). From the results of this part of the study, a new policy has been introduced to encourage the presentation of suspected mild tendon injury cases for diagnostic ultrasonographic examination at an early stage.

In conclusion, this study has demonstrated that the annual percentage of horses retiring from racing at the HKJC increased from 18.5% (193/1045) in 1992-93 to 28.8% (412/1432) in 2003-04. The most important single reason recorded for retirement was tendon injury and the percentage of horses retiring due to tendon injury has risen from 2.3% (24/1045) to 4.2% (60/1432), over the same period. The overall aim of epidemiological research being conducted at the HKJC is to reduce the number of horses that are replaced each season. This will have major economic benefits for the racing industry in Hong Kong and further case control studies will identify risk factors for the major reasons for retirement, thus also improving equine welfare.

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Discussion

A number of studies have highlighted the importance of tendon injuries to Thoroughbred horses but few have provided population based data on the quantitative contribution of this injury to racehorse longevity, performance and associated economic losses in the racing career. The structure of racehorse management in Hong Kong offers the opportunity to do this and to identify important risk factors for tendon injury. Although the primary purpose of this study is to improve the health of the racehorse population in Hong Kong this study is also of relevance to the Thoroughbred population worldwide.

However it remains an interesting and often repeated problem deciding whether a set of census data is a sample and requires statistical tests.

Statistics as a science provides ways in which one can generalise results from a sample to the population. As this paper is based on complete census data from the whole population the issue of inference from the sample to the population appears to be redundant. One may argue that these data could be interpreted as a sample in time, but it is hardly random and it referred to cumulative data for 12 years - arguably "since records began at the Hong Kong Jockey Club". This study appeared to be justified in not using statistical tests in that the actual true differences were described in the whole population and not estimating these differences from a sample of this population.

It was acknowledged that not all measures are proportions and therefore:
"As this is complete census data, no statistical inference to the population is necessary".

Arguably this is an interesting perspective. Readers must be made to understand that results apply exclusively to this population during this time period. The results appear to have relevance to any other group of horses or even another cohort from Hong Kong. However the intention of the study is to conduct studies to yield data to implement a programme to maximise the health and welfare of Thoroughbred racehorses in Hong Kong. This implies that the research intends to use data from the studies to make inferences about other horses in Hong Kong. It has been observed that male racehorses are more likely than female racehorses to have an injury of interest in the population studied. The argument is that there is no need to perform statistical analysis of this sex distribution because the total population has been studied. But if one wish to infer that one need to monitor male horses more closely for this injury in Hong Kong to improve health and welfare, one must recognize that there might be some variation between the study population and the next cohort group of horses to be studied; statistical inference on the observed data will allow variation to be accounted for that might occur by chance. In this case inferential methods are preferred.

The overall aim of epidemiological research being conducted at the HKJC is to reduce the number of horses that are replaced each season. This will have major economic benefits for the racing industry in Hong Kong. Further case control studies will identify risk factors for the major reasons for retirement, thus also enabling intervention strategy as management tool to monitor the horse welfare effectively.

CHAPTER 4

Evaluation of detailed training data in Hong Kong to identify risk factors for retirement because of tendon injuries in Thoroughbred racehorses

Introduction

Following the identification of Injuries of the SDF tendon as the single most important veterinary medical reason for retirement of racing Thoroughbreds (Chapter 2), descriptive epidemiological techniques were used to study the characteristics of premature retirement associated with tendon injury highlighted the reduction in duration of racing career, number of race starts, and earnings compared with other reasons for retirements (Chapter 3).

Analytical techniques were then used to identify the risk factors for the career ending tendon injuries. Data on variables currently collected by the HKJC were analysed using univariable and multivariable conditional logistic regression techniques in this study (Lam et al 2007c). This process can also identify the strengths and weaknesses of current data collection and areas where additional or more accurate data needs to be collected. These analyses provide useful references to develop intervention strategies to reduce the risk of injury, to prioritise areas for future research and to develop novel causal hypotheses for these injuries.

Epidemiology uses the power of scientific analysis to provide evidence that an exposure may be associated with developing or preventing an outcome of event. Sometimes, however, the most basic methods of epidemiology are not enough to determine "the causes of happenings," or whether an exposure is truly associated with an outcome of event. Other exposures or characteristics among the population may be confounding the exposure-outcome relationship (Dahoo et al 2003). Logistic regression and matching data are known methods to deal with confounding factors in large dataset. Logistic regression is an efficient way to control for many potential confounders at one time. Matching, if done correctly when planning the study design for the investigation, reduces confounding before the analysis even begins. In this study, it was the lack of the need to account for seasonal differences between case and control is the result of the matching.

Evaluation of detailed training data to identify risk factors for retirement because of tendon injuries in Thoroughbred racehorses

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Objective—To identify the risk factors for premature retirement because of tendon injury in a Thoroughbred racehorse population.

Animals—175 Thoroughbred racehorses (cases) at the Hong Kong Jockey Club that were retired from racing because of tendon injury between 1997 and 2004 and for which the last preretirement exercise was at a fast pace were each matched with 3 control horses that were randomly selected from all uninjured horses that had galloped on the same date as that last exercise episode.

Procedures—Training data for all horses were examined. Conditional logistic regression analyses were performed to identify risk factors for retirement from racing attributable to tendon injury. Two multivariable conditional logistic regression models were created; each contained 8 explanatory variables.

Results—Compared with control horses, case horses were older at the time of import, accumulated more race distance soon after import, were more likely to have had previous official veterinary or ultrasonographic examinations, raced fewer times during their career, and were in training for a longer period and had exercised at a reduced intensity during the 180-day period preceding the last fast-paced work date.

Conclusions and Clinical Relevance—In addition to identification of risk factors for tendon injury among racing Thoroughbreds, results have suggested that resources focused on obtaining accurate training data may be misdirected in the absence of internationally agreed criteria for incident tendon injury among racehorses. Nevertheless, changes in training intensity and findings of previous clinical examinations could be used to identify horses at risk of tendon injury–associated retirement. (*Am J Vet Res* 2007;68:1188–1197)

Injuries of the SDF tendon are common debilitating problems among Thoroughbred racehorses worldwide.[1-8] In Hong Kong, such injuries are the single most important veterinary medical reason for retirement of racing Thoroughbreds.[9] The annual incidence of SDF tendon injury–related retirement increased from 2.3% to 4.2% between 1992 and 2004.[10] Among the racehorse population during that period, premature retirement associated with tendon injury reduced the duration of racing career, number of race starts, and earnings by 25.6%, 41.2%, and 53.3%, respectively. Thirteen percent of horses that retired as a result of tendon injury never raced in Hong Kong.[10]

Several risk factors for tendon injury in horses during racing have been identified in previous studies.[3,4,11-13] These include horse-related factors such as age, sex, weight, previous steeplechase experience, and SDF tendon abnormalities detected during prerace examination and course-related factors such as racecourse, surface, and distance.[3,4,11-13]

It has been suggested that tendon injury is associated with exercise intensity and duration; however, in most studies, accurate data on exercise carried out during training are not available. In Hong Kong, daily exercise data for racehorses have been recorded since 1996. The purpose of the study reported here was to identify the risk factors for premature retirement because of tendon injury in a Thoroughbred racehorse population through analysis of detailed training data.

Abbreviations

SDF	Superficial digital flexor
HKJC	Hong Kong Jockey Club
VIF	Variance inflation factor
OR	Odds ratio
CI	Confidence interval
HK$	Hong Kong dollars

Materials and Methods

Study population—Details of the horse population, training facilities, and procedures of veterinary in-

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spections to evaluate the suitability of horses to race in Hong Kong have been previously described.[14,15] Briefly, horse racing in Hong Kong consists entirely of flat racing. The season runs from July 1 to June 30 the following year, with races taking place from late August or early September through to the end of June. All racehorses are stabled at Sha Tin racecourse where a maximum of 1,200 horses can be accommodated at any 1 time. All clinical care is provided by a team of veterinarians employed by the HKJC.

Horses in which an injury has been diagnosed must pass an official veterinary examination before they are allowed to race again. Horses can potentially remain in training and racing until compulsory retirement at 10 years of age. Premature compulsory retirement may also occur following 2 officially recorded episodes of either epistaxis or heart rhythm irregularity. Horses can be retired voluntarily at any time during their racing career.

Data collection—For each horse, data of epidemiologic interest including details of the horse, race career, earnings, and racing and medical histories were obtained from the official computerized Jockey Club information system **(Appendix)**. Training work distances and times were obtained from a local commercial trackwork database group.[a]

HKJC database—The HKJC began computerized data collection in 1972. In 1992, an official racing information system was established; a separate veterinary system within the racing information system (designed to store all veterinary clinical records) was established in 1996. At the time of the study, the racing information system database consisted of > 3,700 fields in > 400 database tables, in which clinical records and other related information (eg, racing history and horse and owner details) were collected. Officially published data and clinical record entries were routinely validated by internal audit processes.

Trackwork database and limitations—A local commercial trackwork database group[a] recorded daily training data since July 1, 1996, for all racehorses in Hong Kong. A team of 8 experienced observers recorded the daily trackwork activities of horses with the aid of binoculars from different observation points at Sha Tin racecourse. Each horse was exercised with a numbered and color-coded (associated with year of import) saddlecloth. According to the Rules of Racing, trainers are required to have each of their horses display the correct saddlecloth during trackwork. The Duty Stipendiary Steward performs random inspections during trackwork to ensure that the saddlecloth matches the freeze brand number on the left shoulder of the horse. A penalty fine may be imposed for use of incorrect saddlecloths, and in the last 10 years, there have been no more than 10 discrepancies reported. For any given horse, the estimated distance covered at trotting or canter pace on the all-weather tracks was calculated by multiplying the number of circuits observed by the mean circumference of the specified track.

Case definition and selection—Between July 1, 1997, and June 30, 2004, 337 of 3,585 (9.4%) horses were retired as a result of tendon injury. Three horses with traumatic tendon injuries (eg, lacerations and wounds), 1 with hind limb tendon injury, and 1 with extensor tendon injury were excluded from the potential case population. The remaining 332 horses that were retired because of strain injuries to forelimb tendons were eligible for inclusion as case horses in the study. Only horses that performed work at a fast pace (eg, training gallop, barrier trial [a form of race practice], or race) as their final exercise event prior to retirement attributable to tendon injury were included in the study. This definition was used in an attempt to identify the date of tendon injury, as it was assumed that horses performing work at a fast pace were free from serious tendon injury at that point in time.

Control horse selection—For each case horse, 3 matched control horses were selected at random from all other horses that raced, performed a barrier trial, or galloped during training on the same day as that defined as the last date on which the case horse undertook exercise at a fast pace. Exact exercise periods prior to the final fast work dates could then be examined for both case and control horses without the need to account for seasonal differences in exercise intensity. Exercise intensity was measured in terms of number of episodes and total distance covered for each type of exercise, including trotting in ring (warm-up), trotting or canter exercise, galloping, barrier trial, and racing.

Statistical analysis—Univariate conditional logistic regression was performed with the outcome being retirement attributable to tendon injury. All variables with a value of $P \leq 0.25$ identified in the univariate screening process were available for inclusion in the final multivariable model. Multivariable conditional logistic regression models that accounted for confounding of explanatory variables were developed by use of a forward selection procedure. Variables with strong a priori biological reasons for inclusion were also considered in the final model if they significantly reduced the residual deviance of the model (likelihood ratio; $P < 0.05$). Collinearity of continuous explanatory variables in the final models was assessed by examination of the VIFs with computer software.[16,b]

Two multivariable models were developed. The first included all eligible variables. In the second, risk factors that were not considered to be part of the causal web were removed **(Figure 1)**. For both models, the deviance residuals versus the individual observations were plotted to assess goodness of fit. Observations with large deviance residuals were excluded from the dataset, and the models were refitted to evaluate the influence of the removed observations on the estimated ORs and variables retained in the models.[17] A statistical package[c] was used for the conditional logistic regression analysis.

Results

One hundred seventy-five of the 332 horses that were retired from racing because of tendon injuries met the case definition (ie, were doing fast-paced work as their final exercise prior to retirement), and 525 horses were selected as control horses.

Univariate analysis—The univariate relationships between independent variables and retirement from tendon injuries were evaluated (**Tables 1 and 2**). With regard to horse details, the likelihood of retirement attributable to tendon injuries was strongly associated with age at the time of the final fast-paced work. This was identified when age was entered as a continuous (OR, 1.19; 95% CI, 1.07 to 1.33; $P = 0.002$) or categoric variable, with the odds being highest for horses in the 5-year-old group (OR, 2.34; 95% CI, 1.44 to 3.81; $P < 0.001$).

Retirement attributable to tendon injury among racehorses was also associated with the number of years in training in Hong Kong (OR, 1.16; 95% CI, 1.04 to 1.29; $P = 0.008$) and being a sexually intact male (OR, 2.32; 95% CI, 1.12 to 4.78; $P = 0.03$); the association with a change of trainer was less strong (OR, 1.29; 95% CI, 0.9 to 1.9; $P = 0.17$). Although age at time of import into Hong Kong (OR, 1.17; 95% CI, 0.86 to 1.58; $P = 0.33$) was weakly associated with retirement because of tendon injuries, it was included in the multivariable analysis because of a priori evidence for age as a risk factor in a previous study.[13]

Retirement and race career—Increased odds of retirement attributable to tendon injury were associated with the age at first race in Hong Kong (OR, 1.42; 95% CI, 1.05 to 1.91; $P = 0.02$) but not with the number of race starts (Table 1). This included the total number of race starts (comprised of overseas race starts [OR, 0.99; 95% CI, 0.98 to 1.01; $P = 0.23$] and the number of races in Hong Kong [OR, 0.99; 95% CI, 0.98 to 1.0; $P = 0.16$]). The number of races per year in Hong Kong was strongly associated with a reduced likelihood of retirement attributable to tendon injury (OR, 0.88; 95% CI, 0.84 to 0.92; $P < 0.001$), as were cumulative distances raced during the entire career (OR, 0.99; 95% CI, 0.98 to 1.01; $P = 0.02$) and cumulative distances raced per year (OR, 0.91; 95% CI, 0.88 to 0.94; $P = 0.08$).

Career earnings of racehorses in Hong Kong were examined as a proxy measure of performance of the horses. As a result of the skewed distribution and the extreme range of the continuous variable of earnings per year ($0 to $6.6 million/y in HK$), the variable was log transformed to normalize the distribution. The natural logarithm forms of earnings per year were associated with the likelihood of retirement attributable to tendon injury (OR, 0.94; 95% CI, 0.88 to 1.0; $P = 0.05$). Earnings per year, in the form of a piecewise linear relationship derived from the log-transformed variable, were also associated with the likelihood of tendon injury–related retirement. There was a constant likelihood of retirement attributable to tendon injury in the lower earnings group (earnings ≤ HK$ 1.1 million/y; OR, 0.97; 95% CI, 0.9 to 1.03; $P = 0.29$) followed by a linear reduction in the odds of being a case horse as earnings increased from HK$ 1.1 million/y to a maximum of HK$ 6.6 million/y (OR, 0.78; 95% CI, 0.5 to 1.23; $P = 0.05$).

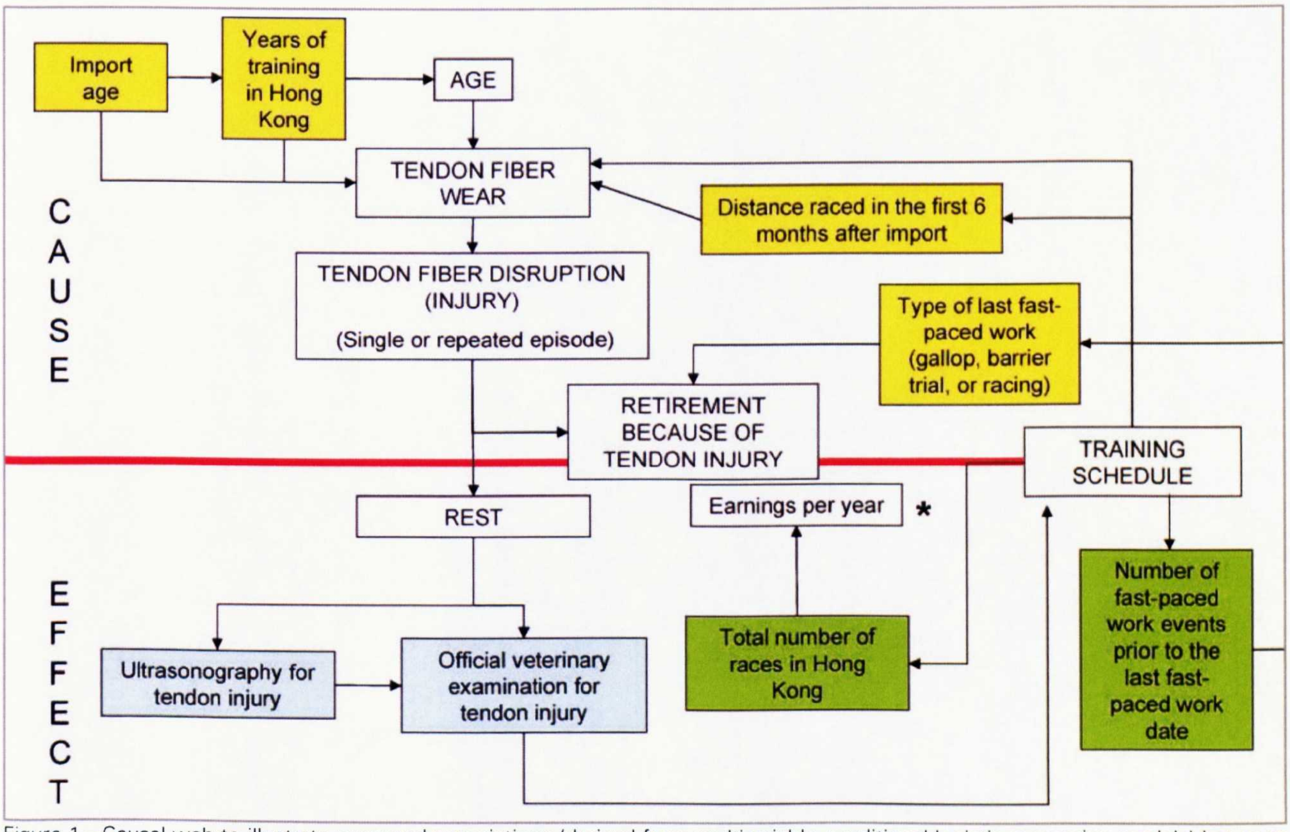

Figure 1—Causal web to illustrate proposed associations (derived from multivariable conditional logistic regression models) between explanatory variables and retirement from racing attributable to tendon injuries among 175 case and 525 control racehorses in Hong Kong. Explanatory variables are considered most likely to be causal risk factors (yellow) or an effect of tendon injury (blue); variables highlighted in green are also most likely to be an effect of previous tendon injury (given the direction of the association [ie, OR < 1). Earnings per year* may be regarded as either an effect of tendon injury or potentially a proxy measure of the quality of the horse, which itself may be associated with the likelihood of retirement attributable to tendon injury.

Table 1—Results of univariate conditional logistic regression analysis of horse details, training and racing variables, and medical history in association with retirement from racing attributable to tendon injuries among 175 case and 525 control racehorses in Hong Kong.

Variable	OR	95% CI	*P* value	Likelihood ratio *P* value	No. of matched data sets used
Horse details					
Age at final fast work event*	1.19	1.07–1.33	0.002	0.002	175
Age at final fast-paced work event†					
2- and 3-year-old group‡	1				175
4-year-old group	1.27	0.78–2.07	0.34		
5-year-old group	2.34	1.44–3.81	< 0.001		
6-year-old group	1.58	0.86–2.92	0.144		
7- to 9-year-old group	1.99	1.12–3.55	0.02	0.006	
Duration of training and racing career in Hong Kong (y)*	1.16	1.04–1.29	0.008	0.008	175
Sex (excluding 3 females [missing values])					
Gelding‡	1				175
Sexually intact male	2.32	1.12–4.78	0.02	0.03	
Change of trainer at any time					
No‡	1				175
Yes	1.29	0.9–1.9	0.17	0.17	
Age at time of import into Hong Kong*	1.17	0.86–1.58	0.32	0.33	175
Race career					
Age at first race in Hong Kong*	1.42	1.05–1.91	0.02	0.02	157
No. of races overseas before import into Hong Kong*	1.02	0.97–1.08	0.43	0.43	175
Total No. of race starts*	0.99	0.98–1.01	0.24	0.23	175
No. of races in Hong Kong prior to the last fast-paced work event date*	0.99	0.98–1.01	0.17	0.16	175
No. of races per year in Hong Kong prior to the last fast-paced work event date*	0.88	0.84–0.92	< 0.001	< 0.001	175
Cumulative distance (km) in Hong Kong up to the last fast-paced work event date*	0.99	0.98–1.01	0.03	0.02	175
Cumulative distance (km) per year in Hong Kong prior to the last fast-paced work event date*	0.91	0.88–0.94	< 0.001	0.08	175
Raced in Hong Kong at any time prior to the final fast-paced work event date					
No‡	1				175
Yes	1.02	0.58–1.78	0.94	0.94	
Earnings per year (HK$)					
per HK$ 1,000 (ln transformed)*	0.999	0.999–1.0	< 0.001	< 0.001	175
per HK$ 1,000*	0.94	0.88–1.0	0.05	0.05	175
Earnings per year (piecewise linear [ln transformed])§					
HK$ 0–1.1 million	0.97	0.90–1.03	0.29		175
HK$ 1.1–6.6 million	0.78	0.50–1.23	0.05	< 0.001	175
Racing intensity after import into Hong Kong					
No. of cumulative races 0 to 90 days prior to last fast-paced work event	0.78	0.49–1.22	0.27	0.26	172
Cumulative distance (km) of races 0 to 90 days prior to last fast-paced work event	0.80	0.56–1.17	0.25	0.22	172
No. of races 0 to 180 days prior to last fast-paced work event*	0.87	0.76–0.99	0.03	0.03	170
Cumulative distance (km) of races 0 to 180 days prior to last fast-paced work event*	0.90	0.82–0.99	0.04	0.03	170
No. of races 181 to 360 days prior to last fast-paced work event*	0.87	0.79–0.96	0.005	0.004	144
Cumulative distance (km) of races 181 to 360 days prior to last fast-paced work event*	0.91	0.86–0.98	0.008	0.006	144
No. of races 0 to 360 days prior to last fast-paced work event*	0.88	0.82–0.95	< 0.001	< 0.001	144
Cumulative distance (km) of races 0 to 360 days prior to last fast-paced work event*	0.92	0.87–0.97	0.001	< 0.001	144
Training and racing intensity prior to last fast-paced event					
Type of last fast-paced work before retirement					
Gallop-pace trackwork‡	1				175
Barrier trial	7.30	3.10–17.20	< 0.001		
Race	3.21	1.74–5.93	< 0.001	< 0.001	
Medical history					
History of ultrasonographic examination for diagnosis of tendon injury					
No‡	1				175
Yes	11.47	7.28–18.07	< 0.001	< 0.001	
History of official veterinary examination for tendon injury					
No‡	1				175
Yes	35.03	12.62–97.21	< 0.001	< 0.001	
History of anti-inflammatory treatment (phenylbutazone)					
No‡	1				175
Yes	1.63	1.07–2.5	0.024	0.021	

*Continuous variable. †Categoric variable. ‡Reference category. §Constant level of risk in earnings per year between HK$ 0 to 1.1 million followed by a linear reduction in risk from earnings > HK$ 1.1 to 6.6 million. ln= Natural log.

Retirement and racing intensity after import to Hong Kong—Both the number of races and cumulative distance raced during a number of time periods after import to Hong Kong were strongly associated with a reduced likelihood of retirement attributable to tendon injury (Table 1). The ORs, 95% CIs, and *P* values for number of races during specified time periods were calculated for 0 to 180 days after import (OR, 0.87; 95% CI, 0.76 to 0.99; $P = 0.03$), 181 to 360 days after import (OR, 0.87; 95% CI, 0.79 to 0.96; $P = 0.004$), and 0 to 360 days after import (OR, 0.88; 95% CI, 0.82 to 0.95; $P < 0.001$). During the first 90 days after import, there was a weak association between the likelihood of retirement attributable to tendon injury and both the number of races and cumulative distance raced (OR, 0.78; 95% CI, 0.49 to 1.22; $P = 0.26$).

Retirement and training and racing intensity (assessed for periods preceding the final fast-paced work event)—The number and cumulative distance (in kilometers) of races were strongly associated with reduced odds of retirement attributable to tendon injury for 90-day periods up to 360 days before the last fast-paced work date ($P < 0.001$; Table 2). The number and cumulative distance of all fast-paced work events during 90-day periods up to 540 days before the last fast-paced work date were strongly associated with a reduced likelihood of retirement attributable to tendon injury ($P \leq 0.001$). The number and cumulative distance of training gallops during 90-day periods up to 540 days before the last fast-paced work date were also associated with the likelihood of tendon injury–related retirement ($P \leq 0.01$). The number of episodes (exercise events on the training or race track) and distance covered during trotting and canter exercise were strongly associated with reduced odds of retirement attributable to tendon injury in the 90-day periods from 0 to 360 days ($P < 0.001$) and 91 to 360 days ($P \leq 0.015$) before the last fast-paced work date, respectively. However, the number and cumulative distance of all fast-paced work events and trotting or cantering exercise in the periods of 30, 60, and 360 days before the last fast-paced work date were not associated with tendon injury–related retirement among racehorses.

When compared with gallop-pace trackwork, the likelihood of tendon injury retirement was strongly associated with the type of final fast-paced work, namely barrier trial (OR, 7.3; 95% CI, 3.1 to 17.2; $P < 0.001$) and racing (OR, 3.2; 95% CI, 1.74 to 5.93; $P < 0.001$).

Retirement and medical history—History of a previous ultrasonographic examination for tendon injuries (OR, 11.5; 95% CI, 7.28 to 18.07; $P < 0.001$), official veterinary examination for tendon injuries (OR, 35; 95% CI, 12.62 to 97.21; $P < 0.001$), and previous anti-inflammatory drug treatment (OR, 1.63; 95% CI, 1.07 to 2.5; $P = 0.02$) were all strongly associated with an increased likelihood of retirement attributable to tendon injuries (Table 1).

Table 2—Results of matched univariate analysis of training and racing variables assessed in 90-day periods preceding the last fast-paced work date in association with retirement from racing attributable to tendon injuries among 175 case and 525 control racehorses in Hong Kong. For each variable, values represent (in descending order) the OR, *P* value, and 95% CI. Significance set at $P < 0.005$.

	Period (d) prior to last fast-paced work date before retirement of case horses							
Variable	**0–90**	**91–180**	**181–270**	**271–360**	**361–450**	**451–540**	**541–630**	**631–720**
Racing intensity No. of races	0.67 < 0.001 0.59–0.77	0.60 < 0.001 0.52–0.7	0.64 < 0.001 0.54–0.75	0.68 < 0.001 0.58–0.79	0.88 0.12 0.75–1	0.90 0.29 0.74–1.1	0.94 0.57 0.76–1.16	0.83 0.14 0.65–1
Cumulative race distance (km)	0.78 < 0.001 0.72–0.85	0.72 < 0.001 0.66–0.8	0.78 < 0.001 0.7–0.86	0.79 < 0.001 0.72–0.88	0.91 0.09 0.82–1	0.95 0.39 0.8–1.1	1.0 0.57 1	0.86 0.07 0.72–1
Total fast-paced work intensity (gallop in training, races, or barrier trials) No. of fast work episodes	0.85 < 0.001 0.82–0.88	0.85 < 0.001 0.83–0.88	0.87 < 0.001 0.83–0.9	0.89 < 0.001 0.86–0.92	0.92 0.001 0.89–0.96	0.93 0.001 0.89–0.97	0.97 0.13 0.92–1	0.96 0.1 0.91–1
Cumulative distance (km) of fast-paced work events	0.87 < 0.001 0.84–0.9	0.85 < 0.001 0.83–0.89	0.86 < 0.001 0.83–0.9	0.89 < 0.001 0.86–0.92	0.93 0.001 0.9–0.96	0.95 0.001 0.91–0.99	0.97 0.26 0.93–1	0.95 0.05 0.9–1
Gallop in training intensity No. of gallop-pace exercises	0.84 < 0.001 0.8–0.87	0.84 < 0.001 0.8–0.87	0.87 < 0.001 0.83–0.9	0.89 < 0.001 0.85–0.92	0.91 0.001 0.87–0.95	0.92 0.002 0.88–0.97	0.97 0.15 0.92–1	0.96 0.18 0.91–1
Cumulative distance (km) of gallop-pace exercises	0.84 < 0.001 0.81–0.87	0.83 < 0.001 0.79–0.86	0.86 < 0.001 0.82–0.9	0.87 < 0.001 0.83–0.91	0.91 0.001 0.87–0.95	0.93 0.01 0.88–0.98	0.98 0.39 0.93–1	0.96 0.14 0.91–1
Trotting or cantering exercise intensity No. of trotting or cantering execises	0.97 < 0.001 0.96–0.99	0.95 < 0.001 0.93–0.97	0.95 < 0.001 0.93–0.97	0.96 < 0.001 0.93–1	0.98 0.15 0.96–1	0.99 0.46 0.96–1	1.0 0.62 1	0.98 0.35 0.95–1
Cumulative distance (km) of trotting or cantering exercises	1.0 0.27 0.99–1	0.98 < 0.001 0.97–0.99	0.98 < 0.001 0.97–0.99	0.99 0.015 0.98–1	1.0 0.55 1	1.0 0.51 1	1.0 0.57 1	1 0.72 1

Multivariable analysis—Two multivariate models were developed, and a causal web was constructed to identify the potential relationships between factors that were considered likely to be causally associated with retirement attributable to tendon injuries (Figure 1).

Model 1 (all variables)—Horses that were older at the time of import into Hong Kong were more likely to be retired from racing because of tendon injury (**Table 3**). For every additional year of age at import, horses were at least 2.5 times as likely to be retired as a result of tendon injury (OR, 2.51; 95% CI, 1.3 to 4.87; $P = 0.006$).

Distance raced in the first 6 months after import to Hong Kong was also associated with increased odds of retirement attributable to tendon injury. For every additional kilometer raced in this period, the odds of tendon injury–related retirement increased 1.24 times (95% CI, 1.04 to 1.48; $P = 0.018$). In contrast, an increased number of fast-paced work events in 90-day periods up to 180 days prior to the last fast-paced work date was associated with a reduced likelihood of a horse becoming retired because of tendon injury (ie, likelihood of becoming a case; OR, 0.86 [95% CI, 0.81 to 0.91; $P < 0.001$] for the 0- to 90-day period and OR, 0.92 [95% CI, 0.87 to 0.98; $P = 0.005$] for the 91- to 180-day period). Barrier trial and racing as the last fast-paced work event were also associated with an increased likelihood of retirement attributable to tendon injury with an OR of 10.96 (95% CI, 2.33 to 51.49; $P = 0.002$) and 10.12 (95% CI, 3.09 to 33.17; $P < 0.001$), respectively.

Previous evidence revealed that tendon injury was an important risk factor. Case horses were more likely to have had a previous tendon ultrasonographic examination (OR, 10.91; 95% CI, 4.84 to 24.59; $P < 0.001$) or official veterinary examination because of tendon injury (OR, 19.39; 95% CI, 4.01 to 93.79; $P < 0.001$) than control horses. There was a reduction in the likelihood of retirement attributable to tendon injury as natural log earnings per year increased (OR, 0.63; 95% CI, 0.53 to 0.75; $P < 0.001$).

Model 2 (removal of variables unlikely to be part of the causal web)—A second model was built without ultrasonographic and official veterinary examination variables. The risk factors identified in the first model remained, but 2 additional factors were identified; horses that remained in training and racing in Hong Kong longer had increased odds of tendon injury–related retirement (**Table 4**). The OR was 3.13 (95% CI, 1.89 to 5.17; $P < 0.001$) for every additional year in training. An increased number of races in Hong Kong was associated with a reduced likelihood of a horse being retired because of tendon injury (ie, likelihood of becoming a case horse; OR, 0.89; 95% CI, 0.84 to 0.94; $P < 0.001$). Estimates for the ORs related to the type of last fast-paced work were significantly reduced in the second model (barrier trial OR decreased from 11 to 6.08 [95% CI, 1.68 to 21.99; $P = 0.006$]; racing OR decreased from 10.1 to 5.94 [95% CI, 2.41 to 14.68; $P < 0.001$]). In this model, earnings per year in a piecewise linear form provided the best fit for the model. There was a gradual reduction in the likelihood of retirement attributable to tendon injury as earnings per year increased from HK$ 0 to 1.1 million (OR, 0.81; 95% CI, 0.71 to 0.94; $P = 0.004$), followed by a much greater reduction in the odds of tendon injury–related retirement for horses earning < HK$ 1.1 million/y up to a maximum of HK$ 6.6 million/y (OR, 0.001; 95% CI, 0 to 0.31; $P = 0.017$). Odds ratios for other risk factors in model 2 were not significantly altered.

Colinearity diagnostic evaluations—Examination of VIFs for each of the independent variables revealed that the largest individual VIF scores were associated with the number of episodes of fast-paced work in the 91- to 180-day period prior to the final fast-paced work

Table 3—Multivariable conditional logistic regression model of retirement from racing attributable to tendon injuries among 175 racehorses in Hong Kong: analysis 1 (all potential explanatory variables included; likelihood ratio = 289.4 [9 degrees of freedom]; $P < 0.001$).

Variable	Coefficients	SE	OR	95% CI	P value
Age at time of import	0.92	0.34	2.51	1.30–4.87	0.006
Race distance (km) during first 6 months in Hong Kong	0.21	0.09	1.24	1.04–1.48	0.018
No. of fast-paced work events in periods preceding the last fast-paced work date					
0- to 90-day period	−0.15	0.03	0.86	0.81–0.91	< 0.001
91- to 180-day period	−0.08	0.03	0.92	0.87–0.98	0.005
Type of last fast-paced work before retirement (categoric variable)					
Gallop-pace trackwork*			1		
Barrier trial (race practice)	2.39	0.79	10.96	2.33–51.49	0.002
Race	2.32	0.61	10.12	3.09–33.17	< 0.001
History of ultrasonographic examination of tendon injuries					
No*			1		
Yes	0.29	0.41	10.91	4.84–24.59	< 0.001
History of official veterinary examination for tendon injuries					
No*			1		
Yes	2.97	0.80	19.39	4.01–93.79	< 0.001
Earnings per year (HK$)					
Per HK$ 1,000 (ln transformed)	−0.46	0.09	0.63	0.53–0.75	< 0.001

*Reference category.

Table 4—Multivariable conditional logistic regression model of retirement from racing attributable to tendon injuries among 175 racehorses in Hong Kong: analysis 2 (excluding risk factors considered likely to be intermediate steps on the causal pathway [previous ultrasonographic and official veterinary examination for tendon injury]; likelihood ratio = 233.7 [10 degrees of freedom]; $P < 0.001$).

Variable	Coefficients	SE	OR	95% CI	*P* value
No. of years in training and racing career in Hong Kong	1.14	0.26	3.13	1.89–5.17	< 0.001
Total No. of races in Hong Kong	–0.12	0.03	0.89	0.84–0.94	< 0.001
Type of last fast-paced work before retirement (categoric variable)					
Gallop-pace trackwork*			1		
Barrier trial (race practice)	1.80	0.66	6.08	1.68–22.0	0.006
Race	1.78	0.46	5.94	2.410–14.68	< 0.001
Age at time of import	0.72	0.28	2.06	1.19–3.58	0.01
Race distance (km) during first months in Hong Kong	0.30	0.10	1.35	1.13–1.62	< 0.001
No. of fast-paced work events in periods preceding the last fast-paced work date					
0- to 90-day period	–0.15	0.03	0.86	0.81–0.91	< 0.001
91- to 180-day period	–0.09	0.02	0.91	0.87–0.96	< 0.001
Earnings per year (HK$)					
Piecewise linear analysis§					
0 to 1.1 million	–0.21	0.07	0.81	0.71–0.94	0.004
1.1 to 6.6 million	–6.53	2.73	0.001	0.00–0.31	0.017

*Reference category.
See Table 1 for remainder of key.

date and the history of previous ultrasonographic examination (1.33 from model 1) or the number of years of training in Hong Kong (6.09 from model 2). The mean VIF values were 1.2 and 2.3 for models 1 and 2, respectively.

Goodness of fit of the multivariable models—For model 1, removal of data sets containing observations with the largest deviance residuals had no effect on the variables retained within the final model. However, 4- to 5-fold increases in the estimates for the ORs related to the type of last fast-paced work before retirement and history of previous ultrasonographic or official veterinary examination for tendon injury were identified.

For model 2, removal of data sets containing observations with the largest deviance residuals had no effect on the variables retained within the final model. There was an approximately 2.5-fold increase in the estimate for the OR for barrier trial as the last fast-paced work undertaken. The OR for racing as the last fast-paced work undertaken increased by approximately 30%. The OR for the number of years of racing and training in Hong Kong increased by approximately 65%.

Discussion

The aim and challenge of the present study were to assess the unique training data collected by the HKJC for relationships between a selection of variables and premature retirement of racehorses as a result of tendon injury. Analysis of this data set identified events that occurred at or near the time of importation, performance of ultrasonographic and official veterinary examinations, and reduced exercise frequency in the days preceding retirement as being associated with the likelihood of retirement attributable to tendon injury. Although some of these factors, such as previous ultrasonographic or official veterinary examination, are of value in the management of risk in the racehorse population, they are examples of associations that are unlikely to be causative. Two multivariable models were therefore established to examine the effects of these variables on the likelihood of retirement of racehorses as a result of tendon injuries.

Within the population evaluated, horses that were older at the time of import into Hong Kong and spent longer in training and racing were at greater odds of retirement attributable to tendon injury. This is consistent with findings of a study by Perkins et al,[13] which indicated that older horses were more likely to sustain tendon injuries, compared with 2-year-old horses. It has been suggested that tendon strength gradually diminishes after maturation at a rate that is dependent on the amount of training undertaken.[18] There is evidence that the SDF tendon in adult horses operates close to its physiologic limits during maximal exercise or racing.[19-23] It has been proposed that a combination of exercise- and age-associated microdamage and the limited adaptive ability of the SDF tendon after maturation at 2 to 3 years of age contributes to increased risk of tendon fatigue failure in horses.[19,21,24-27]

In the present study, horses that raced a greater distance during their first 6 months after import were also at greater risk of retirement attributable to tendon injury. It is possible that such horses were already in race training prior to import into Hong Kong, which enabled them to race more often early in their career at the HKJC. Our finding may therefore reflect more extensive exercise-related tendon degeneration in those horses prior to racing in Hong Kong. It was not possible to quantify the size of this effect because exercise history prior to import into Hong Kong was not available. Results of a biomechanical study[19] suggest that excessive exercise at a young age may predispose horses to SDF tendon injury later in life. It is also possible that the case horses in the present study might have had tendon injuries before import. The unknown history of previous tendon injury and unmeasured exercise intensity prior to import may be contributing factors to the increased odds of tendon injury–related retirement among racehorses in Hong Kong. Nevertheless, a limit on the distance raced immediately after import into Hong Kong may reduce the likelihood of horses being retired from racing because of tendon injury later in their careers.

Case horses were more likely to be performing a barrier trial (race practice) or racing rather than galloping in normal training on their last day of fast-paced work prior to retirement. This finding may suggest that these types of exercise are more likely to result in tendon injury. However, it is also possible that some case horses were already injured prior to the defined last fast-paced work date. Further information on the motivation behind trainer decisions to enter horses into barrier trials or races after reduced levels of fast-paced work in training may help to explain the apparent difference in risk associated with different types of fast-paced work. For example, horses that performed a barrier trial as the last type of fast-paced work undertaken may be more likely to be retired because this type of exercise may be used to evaluate horses that have recently recovered from previous tendon injury. The following data obtained in the present study supported this hypothesis: 46% (28/61) of horses that had barrier trial as the last fast-paced work had undergone a previous veterinary or ultrasonographic examination for tendon injury. However, only 25% (113/445) and 38% (73/194) of horses that had training gallop or racing as their final exercise, respectively, had undergone a previous veterinary or ultrasonographic examination.

Both previous ultrasonographic and official veterinary examinations for tendon injury were strongly associated with the likelihood of retirement attributable to tendon injury among the racehorses included in the present study. Although it was not possible to introduce interventions that would reduce the risk of tendon injury, it would be possible to monitor the number of examinations for individual horses at the HKJC in the future. On the basis of those data, it may then be possible to identify those horses with greater potential susceptibility to tendon injury and subsequent retirement from racing. In addition, the reduced amount of fast-paced work undertaken by case horses in the 1- to 90-day and 91- to 180-day periods prior to the last fast-paced work date suggested that these horses most likely already had some form of injury. Thus, identification of changes in training patterns could also be used to enable closer examination of horses at risk, thereby potentially preventing career-ending tendon injury. Specific preventive measures that have been implemented at the HKJC since completion of our study include reviewing training regimens and closer monitoring of horses with a history of ultrasonographic or veterinary examination for tendon injury.

Exclusion of the 2 variables that were considered most likely to be intermediate steps on the causal pathway (ie, previous veterinary or ultrasonographic examination for tendon injury) resulted in some significant changes to the final multivariable model (model 2) in the present study. Most notably, 2 new risk factors were identified, a different best-fitting form of the association with earnings per year was included, and the estimated ORs for both barrier trial and racing as the type of final fast-paced work prior to retirement were reduced by approximately 50%. Although not dramatically changing the overall findings of our study, these changes underscore the value of causal webs and the importance of hypothesis-driven analysis. Without the second model, we would have failed to identify 2 additional risk factors because of the overwhelming presence of 2 other variables that were strongly associated with the outcome but unlikely to play any part in increasing the likelihood of tendon injury–related retirement from racing.

The impact of tendon injury–related retirement of racehorses in Hong Kong has previously been quantified in terms of a 26% reduction in the duration of racing career, a 41% reduction in the number of race starts, and a 53% decrease in career earnings.[10] These observations were consistent with findings in the present study. Case horses had a reduced number of lifetime race starts, compared with control horses, and horses that earned more were less likely to be retired from racing because of tendon injury. It is probable that these factors reflect the effect of chronic or repeated tendon injury, which ultimately results in retirement, rather than being causal risk factors for retirement.

In the present study, the VIFs calculated for both models indicated little evidence of multicollinearity. The mean VIFs were not considerably larger than 1, and the largest VIFs did not exceed a value of 10.[16] The analysis of goodness of fit for both models indicated that there were some influential observations within the original data set. When case-control sets that included these observations were removed, the final multivariable models retained the same risk factors but there were some important changes in the estimated ORs for some variables. On all occasions, the ORs were more removed from 1, indicating that the original model that was based on the full data set provided conservative estimates of the effects of most risk factors.[17]

The unique clinical and trackwork training records available at the HKJC revealed that 47% (156/332) of the horses that were initially eligible for inclusion in the study trotted or cantered (often for many days after their last fast-paced work) before they were retired. One additional noneligible horse did no fast-paced work in Hong Kong before retirement attributable to tendon injury. This may represent an attempt to rehabilitate a horse that had previous tendon injuries or may indicate that serious tendon injuries can also occur during lower intensity exercise. Arguably, there is little incentive for trainers to have horses with mild tendon injuries examined by veterinarians because this is unlikely to change the management of these horses (the most common conservative treatment being rest and rehabilitation).[28,29] An assumption in our study was that a tendon injury that was associated with retirement from racing would occur during exercise at gallop pace. In an attempt to identify the date of injury, we included only those horses for which the last exercise was at a fast pace. This enabled us to compare exercise intensity for case and control horses over the same time periods, thereby removing the effect of seasonal differences in training and racing. However, results of the present study highlight a major problem in the design of this type of study—identification of the time of first tendon injury. There is evidence that we identified risk factors associated with chronic tendon injury in the study of this report, and this is likely applicable to other epidemiologic studies.

Information regarding the distance covered at different velocities by horses during training and racing and regarding the surface characteristics of training and racing tracks was not available for investigation in the present study. Collecting information about these variables remains a challenge. It has been suggested that the development of miniaturized electronic equipment that incorporates global positioning system capabilities may facilitate this process in future studies.[13] However, with respect to tendon injuries in horses, definition of the incident case is the limiting factor in epidemiologic studies rather than the availability of more detailed or accurate training data. Further investigation of the data available at the HKJC by use of survival analysis techniques should remove assumptions about the exact date of injury through analysis of all cases of tendon injury–related retirement and would identify incident cases by selecting those cases with official records of veterinary examinations associated with tendon injury.

a. Turf Timers Co, Jockey Club Trackwork Service Provider, Hong Kong.
b. Stata, version SE 9.2, StataCorp LP, College Station, Tex.
c. Egret, version 2.0.3, Cytel Software Corp, Cambridge, Mass.

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Appendix appears on the next page

Appendix

Racing history, horse details, and training variables investigated in a study to assess risk factors for tendon injury–related retirement from racing among a population of Thoroughbreds in Hong Kong.

Previous racing history and horse details

Horse details
- Sex (male, gelding, or female).
- Age at import to Hong Kong.
- Age at final fast-paced work event.
- No. of years of training in Hong Kong.
- History of change of trainers.

Race career
- Age at first race in Hong Kong.
- No. of months from import to first race in Hong Kong.
- No. of races overseas before import into Hong Kong.
- No. of race starts including overseas records.
- No. of race starts per year in Hong Kong.
- Distance raced per year in Hong Kong.
- Race earnings.
- Race earning per year.

Medical history
- History of previous ultrasonographic examination for diagnosis of tendon injuries.
- History of previous official veterinary examination for tendon injuries.
- History of analgesic or anti-inflammatory treatment (eg, phenylbutazone).

Training and racing intensity variables

Racing intensity after import to Hong Kong
- No. and distance (km) of races prior to the last fast-paced work event from time of import during specified periods (0 to 90 days, 91 to 180 days, 0 to 180 days, 181 to 360 days, and 0 to 360 days before last fast-paced work event) and during entire career.

Training and racing intensity
- Variables were assessed in periods of 0 to 90 days, 91 to 180 days, 181 to 270 days, 271 to 360 days, 361 to 450 days, 451 to 540 days, 541 to 630 days, and 631 to 720 days before the last fast-paced work event.
  Variables included:
  - Type of final fast-paced work: racing, barrier trial (race practice), or gallop exercise.
  - No. of races.
  - Cumulative race distance (km).
  - Cumulative No. of fast-paced work episodes (races, gallops, and barrier trials).
  - Cumulative distance (km) of fast-paced work events.
  - No. of trotting or cantering exercise events.
  - Cumulative distance of trotting or cantering exercise.
  - No. of swim exercise events.

Discussion

The results of this study highlighted the difficulty in identifying incident cases of tendon injury. Changes in training intensity and clinical examination to diagnosis of tendon injuries may be used as management tools to identify "horses at risk" from the clinical database.

There are a number of study design issues from the findings of the study warrant further discussion.

In general, the process of building a logistic model is very similar to that of building a linear regression model. It involves the following steps:

- Laying out a tentative causal web diagram to guide the thinking process.
- Perform unconditional analyses of relationships between predictors and the outcome of interest using a liberal P-value.
- Evaluation of relationships (correlations) among predictor variables.
- Build the model using automated procedures (with caution), forward selection, backward elimination, stepwise selection, best subset regression, or manual model-building guided by a causal web diagram (which is the preferred method in this study to take into account of variables that are biologically meaningful).
- Evaluate confounding.
- Evaluate interaction during the model building process.

The technique of matching characteristics of cases and controls aim to reduce confounding. Logistic regression is the mathematical model that can give an adjusted odds ratio which is controlled for multiple confounders. Unconditional logistic regression is preferred if the number of parameters is small relative to the number of subjects. For example, consider a case-control study of 100 matched pairs making the number of subjects 200. Because of matching 99 dummy variables would be created to represent each pair. Add to this the intercept and the risk factor of interest. The number of parameters would be a minimum of 103. This situation requires conditional logistic regression. A simple rule of thumb is to conduct conditional logistic regression if matching has been done, and unconditional if there has been no matching. A second rule of thumb is when in doubt to conduct conditional because it always gives unbiased results. The unconditional method is said to overestimate the odds ratio if it is not appropriate (Kleinbaum et al 2002). In this study, a matched case-control conditional logistic regression design was therefore adopted given the large number of datasets of 175 matched pairs.

Traditional confounding definitions implicate variables causally associated with the outcome of interest, associated with the exposure of interest, conditional on other variables under consideration, and exclusive of the proposed causal pathway. More recent developments in causal web graphing theory suggest that a variable must be causally associated with both the outcome and the risk factor of interest. Thus, a potential confounding variable must either temporally precede both the outcome and the risk factor or an unmeasured common cause precedes development of both the measured confounding variable and the risk factor of interest which occur concurrently (Hill 1965).

The requisite association between the potential confounding variable and the risk factor of interest (i.e., definition for a potential confounder) shifts or biases the distribution of the risk factor of interest among cases and controls. This 'selection bias' is introduced in lieu of confounding by the match and therefore needs to addressed during data analysis. The two final multivariable models in this study have illustrated this example.

In this study a question arises whether categories for variables should have also been examined to justify the assumptions made for linear associations. As with linear regression, there are inherent assumptions in fitting a logistic regression model. In the case of linearity, any variable that is measured on a continuous scale is assumed to have a linear relationship with the outcome. If the relationship between a continuous predictor and the log odds of the outcome is not linear, one simple approach is to divide the predictor into categories and fit a set of indicator variables in the model. However the two drawbacks to this approach are that one is discarding information by categorising the continuous variable and, if many categories are required to capture the effect of the predictor, then one have to include a lot of indicator variables in the model. The decision on where to divide the categories should be based, if possible, on what would be biologically meaningful (Stevenson 2008).

In the case of skewed nature and the extreme range of the continuous variable such as Career earnings (HK$ 0 to 6.6 M/ year) in Hong Kong were examined as a proxy measure of performance of the horse, the variable was studied as transformed into natural logarithm forms and in the form of a piecewise linear relationship derived from the log transformed variable, to examine the association with the likelihood of retirement due to tendon injury in univariable logistic regression analysis and interaction in the multiple logistic regression model during manual model building process.

Assessment of interaction and confounding in logistic regression models is similar to the process used in linear regression. Confounding is assessed by adding the potential confounding variable to the model and making a subjective decision as to whether or not the coefficient of the variable of interest has changed substantially. Interaction is assessed by adding the cross-product term and determining if the coefficient for the interaction term is statistically significant. However estimation of odds ratios in the presence of interaction deserves some attention. If interaction is present, the odds ratio for the variable of interest has to be determined at a predefined level of the interacting variable because it will vary with the level of the interacting variable. If the interaction is between two dichotomous predictors, the coefficients for the main effects and the interaction term have straightforward interpretations. The coefficient for each main effect represents the effect of that variable in observations in which the other variable is absent. The coefficient term for each variable was subjectively evaluated for interaction as each variable in this study was manually built into the multivariable logistic regression model. Exclusion of the 2 variables that were considered most likely to be intermediate steps on the causal pathway (ie, previous veterinary or ultrasonographic examination for tendon injury) resulted in some significant changes to the final multivariable model (model 2) in the present study. Most notably, 2 new risk factors were identified, a different best-fitting form of the association with earnings per year was included; and the estimated ORs for both barrier trial and racing as the type of final fast-paced work prior to retirement were reduced by approximately 50%. Although not dramatically changing the overall findings of our study, these changes underscore the value of causal webs and the importance of hypothesis-driven analysis. Without the second model, we would have failed to identify 2 additional risk factors because of the overwhelming presence of 2 other variables that were strongly associated with the outcome but unlikely to play any part in increasing the likelihood of tendon injury-related retirement from racing.

Some further examination of the most extreme outlier observations that are most poorly predicted by the final model during the process for assessment of goodness-of-fit may also provide additional information of the variables that had strong interaction or confounding effects. In examination of some of the outliner observations it has become apparent that some horses in the population neither raced nor trained for extended periods of time and had not been diagnosed with any illness or injury. This raised the question, "What is the health status of these horses?"

However, with respect to tendon injuries in horses, definition of the incident case is the limiting factor in epidemiologic studies rather than the availability of more detailed or accurate training data. Further investigation of the data available at the HKJC by use of survival analysis techniques should remove assumptions about the exact date of injury through analysis of all cases of tendon injury-related retirement and would identify incident cases by selecting those cases with official records of veterinary examinations associated with tendon injury. However identification of horses that have not raced or exercised at the track for an extended period of time have prompted a new direction in devising intervention strategy for monitoring health of racehorses in the population with potentially unreported clinical findings.

CHAPTER 5

INTRODUCTION AND IMPACT OF A "TO WATCH" HEALTH MONITORING SYSTEM

Introduction

In an attempt to identify detailed training and racing risk factors for retirement because of tendon injuries (Chapter 4), two variables were derived from the trackwork database; "number of days since last race" and "number of days since last trackwork at the training tracks".

It became apparent from examination of these records that some horses in the population neither raced nor trained for extended periods of time and had not been diagnosed with any illness or injury. This raised the question, "What is the health status of these horses?"
Identification of sick or injured horses at the HKJC depends on their presentation by Trainers to Stable Clinicians. Information on clinical and diagnostic reports, including examination by radiography, ultrasound examination, bone scintigraphy and surgery are then added as "Reported Findings" to the Veterinary Management Information System (VMIS).

The Racing Control or the Department of Veterinary Regulation & International Liaison (DVR&IL) require that horses that have suffered any illness or injury which renders them unfit to race, be subjected to an OVE before entering to race again. Owners are informed of all OVE and they are published on HKJC website.

A second control measure for fitness to race, which applies to all horses, is the Official Pre-race Veterinary Inspection (OPRVI). All horses declared to race are subjected to OPRVI by a panel of at least 2 to 3 Veterinary Officers of the Department of Veterinary Regulation and International Liaison during the morning on the day of racing and all decision-making must be completed by 10:30 am on that day. The veterinary officers also have access to Reported Findings in clinical records.

The minimum inspection requires a trot-up in hand, visual inspection and clinical palpation of the lower front legs of the horse (tendons, ligaments and flexion of joints) to establish a horse's suitability to race. The outcomes of inspection are recorded as Pass, Marginal Acceptable Pass or Unacceptable to race. Between 2004 and 2005, there was a rise of percentage of total declared runners that failed these pre-race veterinary examinations (from 0.78% in 2004 to 0.84% in 2005). This reduced the number of declared starters for the races and was of concern to Racing Control and Club management.

This racehorse health care monitoring system is the subject of continual review by both the Departments of Veterinary Clinical Services (DVCS) and Department of Veterinary Regulation and International Liaison (DVR&IL) to enable continuing improvement in advising Racing Control Stewards on horse health issues including unacceptable race performance, training and racing injuries.

Prior to 2006, Unreported Findings from cases not presented by Trainers to Stable clinicians often remained a challenge to the regulatory management. In particular, moderate to severe pre-existing or recent clinical findings in declared runners, that were not available in clinical history presented at pre-race veterinary inspection (for example, undiagnosed lameness, sore tendon and suspensory ligament) resulted in withdrawal of a significant number of declared runners from racing.

This chapter is central to the idea of the thesis because it's the 'Intervention' that came out of the previous chapters to illustrate 'Epidemiology in Action' from identifying a problem to teasing out reasons or solutions to a suitable intervention. The study describes the intervention strategy process of introducing a system of training and race monitoring system into racing in Hong Kong with culminating in a new "To watch" category of racehorses as clinical health monitoring strategy for horses with potential unreported findings.

Materials and Methods

Monthly review of training and racing patterns- Trackwork and race monitoring system

In 2006 a new initiative was introduced which aimed to identify horses that may have unreported or undiagnosed veterinary conditions. This was a track work and race monitoring system. A programmed ACCESS (Microsoft Inc. USA) database query system was set up to identify racehorses that had not appeared on the training track for at least 30 days and or had not raced for 60 days but were not under Official Veterinary Examination (OVE) restriction to enter to race. The list was generated at the end of each month during the racing season. These horses were then to be presented for veterinary examination.

A new rule of instruction was introduced in Trainers' Handbook to state that The DVR&IL may review the training and / or racing histories of horses from time to time and trainers may be asked to explain any abnormalities in training patterns, or any other evidence, that may be indicative of an unreported injury or illness of a horse. In the event of the detection of any evidence that a significant injury or illness to a horse was not reported to a veterinary surgeon and properly recorded in the DVCS medical records system, a veterinary examination of the horse may be ordered by the Stewards who may then take whatever action they consider appropriate.

Development of To-Watch Clinical Follow Up System

The To-Watch List system aimed to encourage Trainers to present clinical cases at an early stage, to allow continual monitoring of progress, rather than at a late advanced stage that warranted an issue of OVE notice. This system requires that a Veterinary Officer (VO) checks the horses prior acceptance to race again.

The differences between the "To Watch" and OVE systems is summarised in Table 1.

Table 1 Feature of the To Watch and OVE categories

TO WATCH	OVE

A clinical examination only is required.	A track gallop in addition to veterinary inspection.
Owner is not advised. No public announcement. Internal assessment only.	Owner is informed.
Condition is not reported on the Club's website.	Public announcement of OVE findings on HKJC website.
The medication requirements are relaxed compared to the full OVE requirement as the horse does not need to be presented free of prohibited substances. However the Stable Veterinary Surgeon must be satisfied with the condition of the horse prior to arranging the inspection by a Veterinary Officer and the last date of administration of analgesic / anti-inflammatory treatment must be recorded.	All OVE tests must be performed under the same conditions as racing to be free of any prohibited substance in respect to medication and physical therapy procedures except for the special medication procedure implemented for the management of chronic gastric ulceration and respiratory disease.
There is no official restriction for the horse to be entered to race but follow-up examination must be performed prior to entries for accepting to race.	Horse under OVE restriction must pass the OVE examination before the official race entry system allows the horse to be entered to race.

Guideline of To Watch system

As a guideline, a "To Watch" categorisation was issued for minor clinical conditions that satisfy the following criteria:

1. Transient problems with a high probability of resolving uneventfully and with low potential significance for affecting a horse's future suitability to race or,

2. Reoccurrences of chronic conditions that are unlikely to have welfare, performance or safety implications and that are likely to return to the baseline condition uneventfully.

The system is administered by a "Clinical Follow-up Veterinary Examination Notification Form."

Although, the Stable Veterinary Surgeon (VS) is not required to complete the Clinical Follow-up Veterinary Examination Notification Report, the regulatory Veterinary Officer (VO) is unlikely to be satisfied with the condition of the horse, unless it has been re-examined by the Stable VS and a clinical record of the management of the condition is entered in the Veterinary Clinical Services Department's VMIS.

To ensure that horses are not presented to a Pre-race Veterinary Inspection without assessment, a list of horses with outstanding follow-up examination requirements that have entered to race, is issued on the day of entries, so that the Stable VS can follow-up any outstanding cases and an official inspection can be arranged prior to acceptances. However all horses that show significant clinical findings during any official veterinary inspection will be issued with an OVE notice.

The DVR&IL also reviews the medical records and clinical records of all horses and assesses the potential significance of any conditions recorded in a horse's medical history. On receipt of a clinical report that a horse has suffered an injury that is of potential concern but that apparently does not warrant the issue of a full OVE requirement, the DVR&IL will issue a "To Watch" requirement. This means that the horse may not be declared to race until such time as it has been examined and cleared by a veterinary officer.

The impact of the introduction of the track work and race monitoring system and the "To watch" category can only be assessed from a before and after comparison. The introduction of a randomised controlled trial would have been the ideal but this is impossible in the regulatory framework of the HKJC. Three criteria may be used for assessment; the number of pre-race inspection failures; the number of official veterinary examination (OVE) notices issued and the number of horses in the To-watch category.

Statistics

In reference to the earlier study of census data in the descriptive analysis of retirement of horses associated with tendon injuries (Chapter 3), statistical analysis methods are preferred in this study as the results will appear to have relevance to another cohort study from Hong Kong and it is likely to be some variation in the next cohort group of horses to be studied for the effect of intervention strategy. Statistical inference on the observed data will allow variation to be accounted for that might occur by chance. The Mantel-Haenszel chi-squared test was used to determine significant differences of each group in different racing seasons studied. Each group of population is presented as percentage of the total in each year studied with 95 per cent confidence intervals. Chi-squared tests were applied by using EPI-Info 6 (CDC).

Results

Training and Race Monitoring System

The introduction of the Training and race monitoring system has identified no more than 10 horses per month that have been absent from training at the main training tracks for more than 30 days during the racing seasons from 2006 to 2010 (range 0-10; median= 3). The clinical histories and OVEs attributed to these horses were examined that it became apparent that this absence from training and racing was not associated with any declared injury but in most of the cases was identified as a spell of rest period from training.

The number of horses that have not raced for more than 2 months have been no more than 22 horses per month during the study period (range 5- 22; median= 11). The training records of these horses were examined for the pattern of training preparation for the race.

Only 2 cases identified in the study period that were absent from the track or race for 30 or 60 days were reported clinically abnormal by clinicians and warranted official investigation. It was noted to have long spell of rest from last fast work events with finding of tendon injuries one month later.

Failed Official Pre-race Veterinary Inspection

Since the introduction of the Trackwork and Race Monitoring and To- Watch List Systems in 2006/07 racing season, the percentage of racehorses failing the official pre-race vet inspection has decreased slightly 0.83% (0.64-1.02) in 2005/06 racing season year to 0.68% (0.52-0.84) in

2009/10 racing season year, with the exception of 2008/9 (Table 2). Although not statistically significant, as this is a census population rather than a sample, this indicates a reduction of up to 0.21% of total pre-race veterinary inspection in racing season 2009/10 in comparison with racing season 2005/06 (equivalent to an overall 25% reduction).

The majority of horses withdrawn at pre-race inspection were for reasons related to lameness in each racing season (up to 80% of total withdrawals per racing season). Exacerbated lameness from the last gallop was often the case for withdrawals. This may prove difficult to reduce further as most Trainers prepare their horses for the final gallop within 3 days before races. However the total number of withdrawals from tendon and suspensory injuries fell from 12 in racing season 2005/06 to only 6 in 2009/10 despite the continual increasing number of total runners per racing season (8% increase of total runners from 2005/06 to 2009/10). This may be the result of most of the chronic tendon and suspensory cases in the horse population being subjected to continual veterinary monitoring through the To-Watch list systems.

Table 2- Percentage of racehorses failing the official pre-race vet inspection per racing season (2005/2006- 2009/2010)

Season	Number of Racehorses Failing Pre-race inspection (Number / Total Runners)	Percentage of Total Runners Failing Pre-race inspection % (95% CI)	P value
2005/2006	(75/ 9018)	0.83 (0.64-1.02)	p=0.5
2006/2007	(59/ 9083)	0.65 (0.48-0.82)	
2007/2008	(57/ 9136)	0.62 (0.46-0.78)	
2008/2009	(74/ 9179)	0.80 (0.62-0.96)	
2009/2010	(65/ 9736)	0.68 (0.52-0.84)	

Issue of Official Veterinary Examination

There has been substantial decrease of the number of OVE issued since 2006. Their percentage, when expressed as a proportion of the total number of racehorse population is approximately 19% lower in comparison with Racing Season 2005/06 (Table 3). This is highly statistically significant (P=0.0001).

Table 3- Issue of Official Veterinary Examination per racing season (2005/06 – 2009/2010)

Season	Number of Racehorses issued with OVE % (Number / Total horse population)	Percentage of Racehorse Population issued with OVE %(95% CI)	P value
2005/2006	(1003/ 1336)	75.1 (72.8-77.4)	P=0.0001
2006/2007	(835/ 1360)	61.4 (58.8-64.0)	
2007/2008	(771/ 1370)	56.3 (53.7-58.9)	
2008/2009	(888/ 1475)	60.2 (57.7-62.7)	
2009/2010	(896/ 1520)	58.9 (56.4-61.3)	

Horse on the "To-Watch" List

The number of "To Watch" notices issued has increased annually since the introduction of this system in 2006-7 (Table 4). When expressed as a percentage of the total horse population this has been fairly stable each racing reason (range 45% to 48.5%; P=0.9).

Table 4- Issue of "To Watch" list of horses per racing season (2005/06 – 2009/2010)

Season	Number of Racehorses on To-Watch List (Number / Total)	Percentage of Racehorse Population on To-Watch List %(95% CI)	P value
2006/2007	(612/ 1360)	45.0 (42.4-47.6)	P=0.9
2007/2008	(664/ 1370)	48.5 (45.9-51.1)	
2008/2009	(675/ 1475)	45.8 (43.3-48.3)	
2009/2010	(695/ 1520)	45.7 (43.2-48.2)	

Summary of effects of To-Watch List System

Prior to 2006, the only way of identifying horses with a potential health or injury problem was by issue of OVE notice. There were 1003 OVE notices issued. This was equivalent to approximately 80% of the racehorse population in a racing season.

Following the introduction of the To-Watch list system, the OVE rate has fallen to approximately 60% and the To-Watch rate has stabilised at about 55% of the racehorse population. The addition of both OVE and To-Watch events after 2006 would be equivalent to approximately 125% of the total racehorse population per season or approximately 1.25 events per horse per season. These represented the total of injury and illness events.

This suggests that the introduction of To-Watch system has resulted in an increased detection rate of clinical findings from 0.8 to 1.25 events per horse per year. This suggests an additional 0.45 events of illness/ injury events per horse are now being identified. This was associated with a concurrent decrease of approximately 20% OVE issued per racing season. Trainers appear to accept the To-Watch system fairly well as a result.

The annual percentage of total retirement attributed to tendon injuries fluctuates. It has decreased from 13.5% in racing season 2005/06 to 10.2% in racing season 2009/10 (Table 5). This was equivalent to an overall of 24% reduction of retirement from tendon injuries over the 5 year period. This may be the effect of enhanced monitoring of horses with mild tendon injuries through the To-Watch list surveillance to allow Trainers to closely monitor the progress of the horse in continual training but it is impossible to prove.

Table 5- Distribution of Retirements from tendon injuries per racing season (2005/06 – 2009/10)

Racing season	Horses (n)	Number of horses imported (n)	Horses retired (n)	Cumulative incidence of all retirement (%)	Number of horses retired from tendon injuries	Retirement attributed to tendon injuries (%)	Annual incidence rate of retirement from tendon injuries per 1000 horses
2005/06	1336	358	289	21.6	39	13.5	29
2006/07	1360	368	339	24.9	31	9.1	23
2007/08	1370	386	313	22.8	41	13.1	30
2008/09	1475	454	370	25.1	36	9.7	24
2009/10	1523	469	352	23.1	36	10.2	24

Discussion

The development of the “To watch” system at the HKJC is an example of an outcome of epidemiological data analysis. It describes the practical effects of implementing a preventive strategies and the importance of monitoring the effect of these interventions.

Prior to the analysis of data from combined racing and trackwork database and veterinary management information system, there was no official system of detecting horses which were not training or racing. Identification of this population was incidental to the creation of two variables aimed at measuring training and racing intensity; time since last race and time since last training. For most horses these times were short but there were a number of outliers in the population.

Outliers present an interesting challenge in the analysis of large datasets. Most of the literature on outliers relates to their definition, identification and methods of either eliminating them or incorporating them into analytical techniques (Osborne and Overbay 2004) and should be the focus of more detailed investigation (Kazandjian et al 1989).

In this study, it was initially considered that these outliers would represent an injured population. It was only when the clinical histories and OVEs attributed to these horses were examined that it became apparent that this absence from training and racing was not associated with any declared injury but in most of the cases was identified as a spell of rest period from training.

The mechanism for identifying these horses from the database was relatively simple. It could be added as a query to an existing database. Once achieved the next issue was what to do about them.

In theory, the trackwork and race monitoring system introduced in 2006 was a straightforward mechanism of identifying horses that might be suffering illness or injury. Trainers were advised of the new policy of horses requiring official inspections and encouraged to present horses suffering from or recovering from a veterinary problem to their Stable Veterinary Surgeons for clinical investigation.

The simplest and most rational procedure was to introduce a veterinary examination for these horses. Attempts to conduct veterinary inspection resulted in considerable resistance from the trainers. This new policy was perceived to increase the chance of more OVE notices being issued.

Trainers made complaints during the first few months of enforcement of the policy. Their main concern was that, the issue of OVE would potentially have adverse effect on their relationship with racehorse owners. Racehorse owners are informed of the diagnostic findings from any OVE issued. However owners may become dissatisfied with the Trainers concerned if they had not yet briefed the owners of the findings. This concern over the issue of OVE discouraged trainers from presenting clinical cases for diagnostic investigation.

As a result of these concerns, a process of discussion and negotiation between Trainers and the Department of Veterinary Clinical Services, Department of Veterinary Regulation and International Liaison and Racing Control resulted in agreement to introduce an alternative "To-Watch" category.

Horses listed in this category would have received an assessment for minor injuries which are not subject to OVE. This was implemented in April 2006.

The major reason for the resistance was the potential effect of an OVE on the relationship between the owner and trainer and on the public perception of the horse, as findings of OVE notice was published on the HKJC website.

It became clear that, although apparently straightforward and rational, implementation of this track work and race monitoring system would not be feasible. It was only through the process of consultation and negotiation with the "user community" in this case the Trainers, that implementation of a modified Veterinary Monitoring of Racehorses and To-Watch List System was achieved.

This process provided practical experience of the difficulty in introducing a new health policy. This has been documented elsewhere and a full discussion is beyond the scope of this thesis. In a recent UK Medical Research Council document, Craig et al (2008) commented that strategies to encourage implementation of a new policy or complex interventions should be based on an understanding of the behaviours that need to change, the relevant decision-making processes, and the barriers and facilitators of change. If the intervention has to be translated into routine practice, then monitoring should be undertaken to detect adverse events or long term outcomes that could not be observed directly in the current evaluation mechanism.

Wallerstein et al (2011) also reported that an explosion of concern among communities and researchers about widening health inequities in the United States and worldwide was the result of inadequate integration of social epidemiology and community-engaged interventions to improve health equity. Consultation processes appeared to be a key management element in the design of intervention strategies that the user community will actually allow.

The negotiation which resulted in a "To Watch" system appeared to benefit both Trainers and regulators. There was an apparent reduction in OVE of from approximately 0.8 events per horse per racing season to 0.56 OVEs per horse per racing season. This was not simply associated with the transfer of these cases to the "To Watch" list. The total number of OVEs and "To Watch" notices given out exceeded the OVEs in the year before introduction indicating that an additional 0.4 event of illness and injury events in horses that were not previously monitored were being identified by this process.

The effect of this on veterinary clinical services, in terms of increased clinical follow up work on To-Watch cases has provided an enhanced communication link between clinicians and regulatory vets on monitoring the clinical progress of the cases and assessing their suitability to race. Only a small number of horses absent from the track or race for 30 or 60 days were reported clinically abnormal by clinicians and warranted official investigation (for example, long spell of rest from last fast work events with finding of tendon injuries one month later).

There was also evidence that the proportion of horses failing pre-race inspection decreased as a result of this intervention. There was an apparent reduction from 0.83 to 0.68%. Although not statistically significant this was consistent and in terms of the total population at risk represented a real fall in percentage of runners for withdrawals.

There was also an apparent reduction in withdrawals because of tendon and suspensory injuries (50% less in 2009/10 racing season in comparison with 2005/06 racing season). This resulted from most of the chronic tendon and suspensory cases in the horse population being subjected to continual monitoring of progress by veterinary monitoring of trackwork and race periods and To-Watch list systems.

It is also possible that the lower number of OVEs was associated with pre-emptive identification of injuries which prevented them reaching a severity which required an OVE. However no measures of any other outcomes associated with this intervention, for example, number of races run by each horse or decrease in retirement rate, were made. However one objective of the intervention strategy is to enhance surveillance of unreported findings that was achieved through introduction of veterinary monitoring systems.

The main purpose for reporting this study is as an example of the mission critical importance of data analysis and of the consultative and modifying process needed to introduce apparently simple and rational interventions. The objectives and efforts of introduction of a scientifically developed intervention strategy can never be achieved if no one will co-operate with it.

In contrast to monitoring racehorses absent from trackwork and race for extended period of time, the potential relevance of review of the trackwork and race patterns in full training can assist in retrospective investigation of other severe and catastrophic musculoskeletal injuries of racehorses sustained during training and racing. This may be in particular importance to horses suffering from some pre-existing weakness with increasing exercise intensity and cumulative musculoskeletal repetitive stress that puts it at high risk of injury during training and racing. The lack of detailed training data in most published studies has been a limiting factor for the effective retrospective investigation of both athletic performance and incidents of musculoskeletal injury. The next chapter is to discuss a philosophical view point and "Thinking-out-of-the box" approach to investigate the missing data for objectively assessing the risk of injury to an individual racehorse and the cumulative intensity of training and racing stress that causes an individual horse to be a high risk of injury at gallop.

CHAPTER 6

Discussion and The Way Forward

A philosophical view point and "Thinking-out-of-the box" approach to investigate the risk of racehorse injuries

Changes in training intensity and findings of previous clinical examinations have been noted in the matched case-control study that identified risk factors with potential ability to predict horses at risk of tendon injury associated retirement (Chapter 4).

Preliminary proof of concept to predict the risk of tendon injuries was assessed by Support Vector Machine predictive mathematical modelling of over 2 million records of training and race data in 3000 horses over a 6-year period at the Club (Parkin 2007).

The potential research initiative is to be able to obtain an injury risk probability for an individual horse incorporating multiple factors, including the clinical findings noted during a pre-race veterinary inspection, the horse's medication history, pre-existing veterinary conditions and the training volume and intensity over a specified period prior to the ultimate stress test- the race.

The integrated technology (Flight deck recorder concept) for monitoring trackwork and race performance of racehorses can allow standardised review of detailed training data and biometric readings from direct measurement of individual horse to assess progress of performance and effect of track conditions. The development of integrated performance tracking technology is mission critical for the racing industry to optimize horse welfare, safety and racing performance as well as to enhance the integrity of racing.

This discussion chapter addresses a number of philosophical questions on the conceptual development of an integrated technology tool to enable predictive risk analysis aiming to prevent career ending injuries in training and racing.

I. Why are equine racing regulators and equine clinicians often so helpless to explain why an individual horse suffered a catastrophic injury during racing?

All racing regulatory veterinarians in Hong Kong have experienced the gut wrenching feeling of dealing with a racehorse that has suffered a catastrophic racing injury and the adverse effects that these events have on the public perception of the racing industry.

Those of regulatory veterinarians that perform pre-race inspections to assess horses' suitability to race often find themselves asking; "How could I have done better? What did I miss during the Pre-race inspection? How could I have predicted that this horse was at high risk of suffering a catastrophic injury during racing? They find themselves wondering if access to more information on the training, medical and treatment history of individual horse might have helped."

An increasing trend in human medicine is the application of diagnostic computer algorithms to clinical practice. Increasingly there are examples of the artificial intelligence significantly and consistently outperforming experienced clinicians, often because humans are subjectively influenced by suggestion, recent experience, distractions and an inability to accurately weight the influence of multiple variables (Lam and Stewart 2009).

Although those racing regulatory veterinarians that do pre-race veterinary inspections are unlikely to ever concede that their clinical experience and intuition could ever be replaced by artificial intelligence, improved diagnostic technology and supplementary aids to objective decision-making, such advances could help process the multiple variables that contribute to injury and could assist to identify those horses that show no obvious signs of impending catastrophic injury. Increasing exercise intensity and cumulative musculoskeletal repetitive stress has been identified as a risk factor of catastrophic injury during racing (Parkin 2008). In the author's experience, assessing suitability of a horse to race is very much an art. It is currently limited to subjective judgment at the time of clinical examination rather than an informed scientific decision using predictive risk algorithms based on the runner's analyzed records including health history, performance and training data. Detailed training records are often not available in most racing jurisdictions but this is not the case in Hong Kong. Perhaps the critical step to a paradigm shift from art to science in making a decision on suitability to race is a collaborative effort which extends beyond the current model of thinking in the racing industry. The starting point to making better pre-race "suitability to race" decisions is better quality information on which to base these decisions.

II. What is Relevant Decision-making Information?

Many risk factors for catastrophic injuries in Thoroughbred racehorses have been documented by different research groups (Parkin 2008).

In addition to the horse's medication history and the state of any pre-existing injuries and degenerative conditions, the cumulative musculoskeletal stresses of training and racing have been considered to a significant risk factor (Cruz et al 2007).
Several other reports (Parkin 2008) also identify cumulative volume and intensity of repetitive training and racing workload within specified time periods are factors that may contribute to the risk of micro-fractures and catastrophic injuries during high speed exercise.

III. What are the missing data for objectively assessing the risk of injury to an individual racehorse and how can we assess how much training and racing stress causes an individual horse to be a high risk of injury during training?

Access to information about the volume and intensity of an individual horse's workload and, more particularly, the repetitive stresses applied to the individual and how the individual responded to those repetitive stresses is usually very limited.
Is it feasible to develop a training monitoring system, as in an aircraft "Black Box" system, which could track some of the stresses applied to a horse's musculoskeletal system and some of the horse's responses to those stresses?
Is it feasible that we could then retrospectively analyze these data to develop a model that might help predict the risk of injury to horses?

Human Sports Medicine Monitoring

Many strenuous team sports routinely use GPS and monitoring physiological data including heart rates during training and competition to assess players' recovery from exertion during games with the objective of managing player workload, to investigate the occurrence of injury and loss of performance syndromes and to manage rehabilitation from injury (Justham et al 2008 and Snow 2009). The same principle of integrated technology can be applied in the racing industry to improve the science of racehorse training by provision of a monitoring tool for conventional training methodology of individual Trainer's preference.

Technology and Racehorse Training

GPS and heart rate monitoring technology for use in racehorse training is already well advanced and commercially available. However, there has been limited published scientific evaluation of racehorse training programs and the majority of trainers have been slow to adopt available technology.

Most training of racehorses still relies on working horses at certain speeds using a combination of a manual stopwatch, the rider's 'feel' for a horse's work intensity and the art of the trainer in assessing the horse's response to the workout.

Consequently, the actual work intensity and the responses of the horse to the training are difficult to define for the purposes of scientific study.

Recent Developments in Technology

Recently, a system has been introduced on UK racecourses that can provide accurate measurement of racehorses' speed and position during a race.

The data collected by the "TurfTrax" system (http://www.turftrax.com) can provide the precise distance, track going, inclination, rate of turn and pack positioning for each horse that has raced.

Spence et al (2008) showed that the speed profile can be used to examine the level of exertion and influence of racecourse features on the performance of a horse.

While raceday data can be obtained, the lack of detailed training data has been a limiting factor for the effective retrospective investigation of both athletic performance and incidents of musculoskeletal injury.

There is also a need to determine the accelerations acting on the equine hoof under field conditions to better assess the risks for orthopaedic conditions associated with shoeing and training and racing surface conditions.

Schaer et al (2006) described a wireless data acquisition system that has been developed to measure the acceleration profiles generated in Thoroughbred racehorses exercising at high speeds. Impact accelerations, acceleration on break over and take-off and temporal stride parameters were calculated. Impact injury scores were also determined using peak accelerations and the time over which they occurred. Further work is needed to determine if trends exist across a population.

What should a Workload Monitoring System measure?

The following are the fundamental technology requirements for an automated monitoring system.

1. Wireless real-time monitoring of total horse performance.
2. Horse- track surface interaction.
3. Ease of use including fitting as a normal part of tack.
4. Sensors capable of monitoring multi-biometric parameters including:
5. Position
6. Speed
7. Accelerations
8. Stride frequency
9. Stride Length
10. Tri-axial Impact Accelerations
11. Heart rate (including ECG)
12. Body temperature

Putting it all together: Assessing the Risk of Injury in a Racehorse

Currently, the assessment of horse's suitability to race is made by the trainer and private veterinarian in the first instance and, if necessary by an official veterinarian during a pre-race veterinary inspection, but this approach is prone to errors of judgment caused by many factors, not least of which is the lack of objective decision-making information.

In this thesis we show that changes in training intensity and findings of previous clinical examinations could be used to identify horses at risk of tendon injury–associated retirement. This example of using detailed training data to identify risk factors for retirement because of tendon injuries in racehorses at the Hong Kong Jockey Club has confirmed that obtaining reliable training data was an important requirement for identifying the probability of tendon injury among racehorses.

This has led the Hong Kong Jockey Club to further explore the concept of development of the Integrated Trackwork and Racing Monitoring system to assist decision making process in pre-race veterinary inspection procedures.

IV. What is an acceptable rate of injury during racing?

The acceptable rate of injury during racing may well be answered if an Injury Risk Probability Estimate can be formulated. The overall objective of the Hong Kong Jockey Club's initiative is to be able to obtain an injury risk probability for an individual horse. This will be achieved by developing a risk assessment algorithm incorporating multiple factors, including the clinical findings noted during a PRVI, the horse's medication history, pre-existing veterinary conditions and the training volume and intensity and cumulative musculoskeletal repetitive stress over a specified period prior to the ultimate stress test- the race.

The Potential Benefits of an Integrated Workload Monitoring System

An integrated trackwork and race monitoring system (ITRMS) could provide:

1. A training aid for horsemen to optimize horse welfare, safety and racing performance.
2. A research and development tool to assist in minimizing horse injury during training and racing.

3. An aid to decision making on the risk of injury and therefore the suitability of a horse to participate in a race, by providing quantitative analysis from a reliable set of directly measured trackwork and race data.
4. An early injury alert system could be developed as a preventative tool for Trainers to monitor horses in training to detect warning signs and patterns of risk of injury and to seek early veterinary advice so as to minimize training and racing injuries.
5. A real time indicator "dashboard" to work riders and jockeys about the physiological state of their horse.

The "Gmax Equine System" (www.gmaxequine.com), developed by Cambridge Design Partnership in the UK, is one such prototype of integrated Trackwork and Race Monitoring System. Gmax units have been tested over 250 exercise sessions (including fast flat race training, slow work, jockey training, endurance riding and schooling/ horse walker) with more than 60 different horses at 4 different training/ racing locations. In combination with Local Position Measurement, a simulated flat race with high position accuracy was achieved at Magna Racino in Vienna, Austria in 2008.

Stride length calculations have been validated against manual measurement. Accuracy at any point in time was reported to be within 5%, and error when averaged over a straight furlong taken at approximately constant speed was typically less than 10cm (unpublished data).

The ECG recordings were found to be of diagnostic quality by equine cardiologist. A number of previously undetected and potentially performance limiting heart irregularities were diagnosed, including ventricular tachycardia, atrial fibrillation, premature ventricular contractions, and sino-atrial arrest.

The proof of concept of the integrated technology tool has been tested successfully and is in further development to deploy the system on a larger scale with capability of monitoring an unlimited number of horses simultaneously exercising on the same track.

The Black Box Technology for equine application is becoming a reality. The ability of regulatory vets to make better objective decision by on the suitability of a horse to race based on integrated information from all responsible parties involved (including Trainers, Clinicians and Track management) is the ultimate goal of the HKJC as it strives for best practices of equine welfare (Lam and Stewart 2009).

V. What is it worth to the industry to reduce the rate of injury from say 1.4 per 1000 runners to, say 0.4 per 1000 runners?

The number of individuals working in the epidemiology field of horse racing industry is small and it is important that the best use of available data is achieved by establishing local, regional and global alliances. This will enable multi-centred studies to be conducted that have the potential to have a significant impact on the prevalence of injury and fatality in the Thoroughbred (Parkin 2007).

A Havemeyer workshop on Epidemiology of Training and Racing Injuries was held in Hong Kong in 2007 through the network of collaboration among the International Group of Specialist Racing Veterinarians of the International Federation of Horseracing Authorities to build on the International Symposium on the Prevention of Thoroughbred Racehorse Fatalities and Injuries, held in Melbourne, Australia in July 2005 (Parkin 2007).

The objectives of the workshop were to:

- Review advances in the epidemiology of tendon injuries.
- Take stock of the methods and type of data currently recorded in different racing jurisdictions.
- Determine whether coordination and standardization of data from different sources is currently feasible or of potential benefit.
- Explore new opportunities, in light of recent technological advances, for recording more detailed exercise data at a population level.
- Investigate the possibilities of creating industry wide case definitions to enable meaningful comparison between future studies conducted in different locations through international review of risk factors, in particular, related to risk factors indicated in catastrophic fractures.

Following the euthanasia of American public favourite filly Eight Belles in United States in May 2008, after catastrophic injuries to both front fetlocks a quarter mile after finishing second in the Kentucky Derby , members of every sector of the Thoroughbred industry have banded together to proactively address the outcry of public concern on safety and welfare issues. Members of the equine industry together provide an in-depth exploration of catastrophic injuries in the Thoroughbred racehorse, focusing on what veterinarians know about catastrophic injuries based on the available scientific data, and looking at what work needs to be done (Oke 2008). This was followed by official establishment of Thoroughbred Safety Committee by The Jockey Club, United States, in May 2008 to review every facet of equine health and to recommend actions the industry can take to improve the health and safety of Thoroughbreds to restore public confidence in horse racing. The committee involves a cross section of industry representatives, including jockeys, trainers, veterinarians, chemists, pedigree experts, handicappers, owners, breeders, blacksmiths, racing commissioners, racetrack executives and geneticists (**http://www.jockeyclub.com/tsc.asp**).

A continual research initiative to examine the risk factors for proximal sesamoid cases by survival analysis is under investigation at the time of submission of the thesis. Over a 5 year period between racing seasons 2003/04 and 2008/09, the average incidence of Catastrophic Musculoskeletal Injuries (CMI) in HKJC was 0.76 per 1000 starts (+/- 0.21; 95%CI; **Table 1**). The proximal sesamoid fractures have been identified as the majority of the CMI cases (53%) and the priority subject for study in detail.

Table 1- Distribution of Incidence of CMI at HKJC over a 5 year period (2003-2009)

HKJC CMI Descriptions 2003/04- 2008/09	Number of CMI cases	HKJC % of Total CMI
Biaxial Proximal Sesamoid Fracture	20	45.5
Ruptured distal sesamoidean ligament	6	13.6
Humerus Fracture	3	6.8
Scapula Fracture	3	6.8
MTIII Condylar Fracture, P1 & proximal sesamoid Fractures (Hind Leg)	2	4.5

Carpus comminuted fracture	1	2.3
MCIII Lateral condylar fracture	1	2.3
MCIII Medial condylar fracture	1	2.3
Medial proximal sesamoid MCIII condylar P1 fractures	1	2.3
Medial sesamoid	1	2.3
Medial proximal sesamoid fracture, suspensory branch partial rupture	1	2.3
Olecranon fracture	1	2.3
P1 Fracture	1	2.3
P1 and P2 Fracture (Hind Leg)	1	2.3
C2 Neck Fracture	1	2.3
TOTAL	44	100.0

Taking into account of availability of trackwork database from 1997, 169 cases of Proximal Sesamoid Fractures from 1997/98 to 2010/11 were retrieved. Respective profiles on age, career starts, weekly accumulative number and distance of Fast Work Events (including Gallops/ Barrier trails/ Races) are to be studied. Survival analysis is an alternative technique to study the trend of changes of work pattern towards the last fast work event date. This on-going study aims to provide a useful population based data resources for further collaborative research studies to investigate risk factors, including pre-existing lameness history and lay-off periods, medication history, pre-race veterinary inspection findings, training and racing regimes that are potentially associated with increased risk of CMI.

VI. At what point does the law of diminishing returns render the efforts to reduce injury in racehorses impractical?

The management review and experience at the racing jurisdiction at the Hong Kong Jockey Club highlights the balance between veterinary regulation and relationship with Trainers in achieving the operational needs of the business whilst maintaining the colour and sporting aspects of racing and enhancing transparency and integrity in protecting the welfare, health and safety of racehorses and riders.

Official Pre-Race Veterinary Inspections OPRVI carried out at the in Hong Kong Jockey Club between 2006 and 2009 show the following results:

1. 0.7% (+/- 0.1%; 95% CI) of total 27392 runners failed OPRVI. The reasons for withdrawal related mainly to lameness (78%) and tendon or suspensory injuries (21%).

2. 2.1% (+/- 0.2%; 95% CI) of total runners (586/ 27392) were recorded in Marginal Acceptable Pass Category (MAPC) showing a mild degree of lameness or stiff action but not associated with significant clinical conditions.

3. 3.8% (+/- 1.5%; 95% CI) of MAPC were subsequently withdrawn from race.

4. Post-race findings of unacceptable performance or lameness or stiff action were noted in 12.5% (+/- 2.7%; 95% CI) of MAPC.

5. 0.5% of MAPC sustained catastrophic injury, which represented 11% of the total fatalities recorded.

6. The total number of runners returned lame post race represented 0.9% (+/- 0.1%; 95% CI) of all runners.

Prediction of catastrophic injuries remains a challenge. Over 90% of fatalities presented no clinical abnormalities at OPRVI. However the OPRVI strategy prevents horses with obvious clinical abnormalities from exposure to further risk of exacerbating their injuries. Application of technology to generate an injury risk probability for an individual horse, by developing a risk assessment algorithm including the training volume and intensity may further assist informed decision making on suitability to race.

The objectives of veterinary regulation are to protect the safety and welfare of the horse and to contribute to the presentation of a quality wagering product.

The veterinary aspects of Hong Kong racing are already highly regulated. The Law of Diminishing Returns is applicable to the veterinary regulation of horse racing and the Club is already well along the very slowly rising curve of increased effectiveness plotted against veterinary regulatory input.

The Department of Veterinary Regulation and International Liaison (DVR&IL) recognizes that over-regulation carries a potential adverse effect on the overall quality of the racing product. The Club is sensitive to the necessity to maintain a balance between the operational needs of the business and the need to maintain the colour and sporting aspects of racing against the need to enhance transparency, integrity and the protection of the welfare, health and safety of racehorses and riders.

It is possible that the Club is on a plateau of effectiveness in veterinary regulation that can only be significantly improved by the development and application of new technology, especially in the area of detection of the early warning signs of risk of injury and poor racing performance syndromes.

Conclusion and The Way Forward

The research study has enabled understanding causes of retirement of racehorses at the Hong Kong Jockey Club through identification of the reasons for permanent cessation of racing for Thoroughbred horses at the Hong Kong Jockey Club and the risk factors associated with retirement from tendon injuries.

The research findings have provided an evidence based reference to develop and implement intervention strategies in the training of racehorses and management of race tracks in an attempt to minimize the incidence of racing and training injuries.

The objectives of this study in reference to retrospective study of 12 years of racehorse records from July 1992 to June 2004 allowed analysis of historical records and description of reasons for retirement and pattern of wastage of the racing population at the Hong Kong Jockey Club.

In addition, a process of improved recording of retirement and injury data has been devised with a system in place for retirement categorisation and an injuries report form.

The study findings have established research priorities. Epidemiological study of tendon injury will be followed by proximal sesamoid fractures. Continual research work to improve data collection and examine the risk factors involved for different types of racing injuries has been made possible through detailed understanding of information database.

There are remaining Questions to investigate:

Which risk factors increase the risk of these injuries (and re-injuries) especially in our high rating horses?

How do these injuries affect the loss in training time?
(including examination of trackwork records of each injured horse for patterns of days off from training)

What is currently not being collected that would be useful?
(including direct trackwork measurement from individual horse, direct horse-track surface impact characteristics during training and racing from individual horse, etc.)

The future vision is the development of Intervention Strategies (for example, alteration of training pattern for Trainers with high injury rates in an attempt to reduce risk of injury) and development of predictive mathematical models to assess risk of injuries and re-injuries in continual training and racing career of racehorses. Despite the limitations of predictive modelling of injuries in individual animals, the idea of developing risk indicator system in the form of 'traffic lighting' for different risk zones (Green for low risk; Yellow for moderate risk and Red for high risk) can be explored to raise awareness of trainers to subject racehorses to veterinary monitoring in continual full training programme to optimise racing performance and health welfare.

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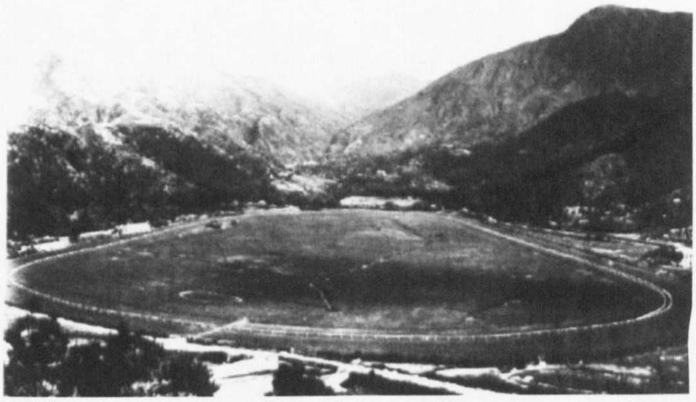
Appendix 1 _General Introduction of Hong Kong Jockey Club

Horse Racing in Hong Kong

I. Origins

Horse racing in Hong Kong commenced in 1841. British colonialists drained an area at Happy Valley in the north of Hong Kong Island (Figure 1). With the exception of a few years during World War II, Happy Valley has seen non-stop action ever since. It is now one of the most famous race tracks in the world. A second racecourse was opened in 1978 at Sha Tin in the New Territories (Figure 2).

Figure 1- Hong Kong Jockey Club Archive Historical Pictures of Happy Valley Racecourse and Race Day Scene in the late 19th Century



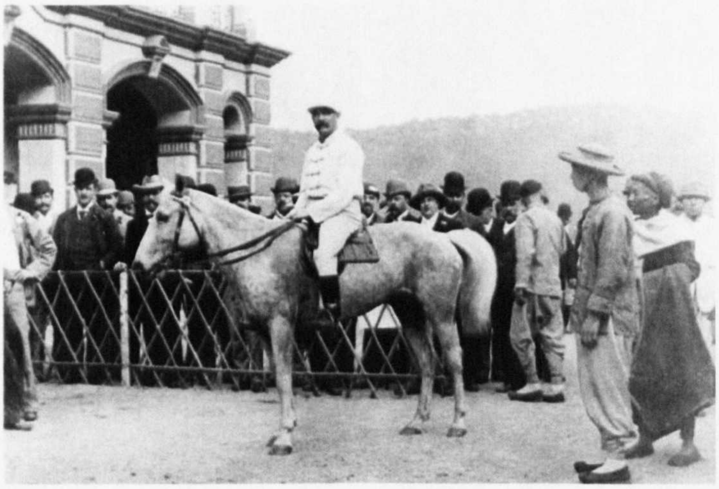


Figure 2- Statellite Map of Sha Tin and Happy Valley Racecourse

The Hong Kong Jockey Club

The Hong Kong Jockey Club (HKJC) was founded in 1884 with the aim of organising horse racing. It was an amateur organisation but raised revenue through commission on betting. This revenue was used to support racing and any excess was donated to charitable causes (**http://corporate.hkjc.com/corporate/history/english/index.aspx**).

In the 1950s, with the influx of immigrants into Hong Kong and the cost of post-war reconstruction its charitable role became integral to its operation. In 1955 the Club formally decided to devote its surplus each year to charity and community projects and in 1959 the Hong Kong Jockey Club (Charities) Limited company was established. In the same year it was granted a Royal Charter by the UK Government and became known as the Royal Hong Kong Jockey Club (**http://charities.hkjc.com/charities/english/index.aspx**).

As the sport increased in popularity so did its revenue from betting. To manage this change, structural and legislative changes were introduced. In 1971 it became a professional organisation and in 1973, off-course betting branches were authorised by the Government. This was introduced to combat illegal bookmaking.

In 1997, with independence the name was changed back to the Hong Kong Jockey Club. It holds a government-granted monopoly in providing betting on horse racing and overseas football events. Its vision is to be a world leader in the provision of horse racing, sporting and betting entertainment, and Hong Kong's premier charity and community benefactor (**http://corporate.hkjc.com/corporate/vision-mission/english/index.aspx**)

In 2009/ 2010 racing season, the total turnover on horse racing was at HK$75.50 billion (approximately US$ 9.4 billion). The HKJC is the largest private donor of charity funds, contributing an average of over HK$1 billion (approximately US$130 million) annually over the past ten years. It is also the largest taxpayer in Hong Kong. The HKJC also provides dining, social and recreation facilities to its approximately 23,000 members.

The HKJC mission is to provide total customer satisfaction through meeting the expectations of all Club customers and stakeholders - the racing and betting public; lottery players; Club Members; charities and community organisations; Government; and ultimately, the people of Hong Kong - and thereby be one of Hong Kong's most respected organizations (**http://corporate.hkjc.com/corporate/vision-mission/english/index.aspx**).

II. Current Structure

i. Race Tracks

There are currently three race tracks and one training track. There are two sand based turf tracks at Happy Valley and Sha Tin and an all-weather 'dirt' track at Sha Tin. A smaller all-weather training track is available at Sha Tin for trotting and canter work on one day a week (Figures 3).

Figure 3- Sha Tin Racecourse Tracks Facility

ii. Horses and Stables

A maximum of 1200 Thoroughbred racehorses are stabled at the Sha Tin Racecourse of the Hong Kong Jockey Club. There are no stud facilities in Hong Kong, so all racehorses are imported, the majority (approximately 70%) from Australia and New Zealand. Most (approximately 70%) are imported as un-raced 2- and 3- year-olds and race until age, performance or health related retirement. There is continual importation and retirement of racehorses throughout the season. On average over 350 horses are imported into the local population each season. Approximately 40 more overseas runners are imported temporarily for international races every racing season. After retirement, there is export of on average over 250 retired racehorses overseas or to mainland China.

iii. Racing

Horse racing in Hong Kong consists entirely of flat racing. There are approximately 700 races per year, 87% are on turf at either Happy Valley or Sha Tin and the remainder on the all weather surface at Sha Tin. The season year runs from 1 July to 30 June the following year, with races taking place from late August or early September through to the end of June or early July.

iv. Handicapping and Race Class Structure

Almost every race in Hong Kong is a handicap event in which horses are weighted according to their ability. Top performance runners, with the highest rating in the race, will carry the most weight and the lowest rated runner carrying the least amount of weight. The weight carried is set by the HKJC Handicapper who keeps track on all horses and continues to rate them on each race performance. The runner will gain or lose rating points from a win or unplaced performance respectively. Every horse in Hong Kong has a rating score and they progress up or down a 'Race Class' (Refer to Race Class Structure) depending on their current rating achieved. The exception to the handicap weights are in stakes races where all the runners carry the same amount of weight.

In all handicaps, the maximum allocated weight is 133lb and the minimum allocated weight is not less than 113lb. Northern Hemisphere-bred and Southern Hemisphere-bred 2-year-olds (as at 31st December) receives a 5lb weight-for-age allowance in all handicaps, where applicable.

There are five Race Classes in addition to Group and Griffin races (**http://www.hkjc.com/english/racinginfo/handicap_policy.asp**).

In handicap races, the standard upper rating limit for each class are as follows:

Race Class	Standard Upper Rating Limit
1	120
2	100
3	80
4	60
5	40

v. Allocation of Ratings

The ownership of racehorses in Hong Kong is controlled by The Hong Kong Jockey Club. Only Club members who have been with The Jockey Club for a specified period of time (currently 12 months) are entitled to the privilege of owning racehorses. The Jockey Club operates a ballot system under which members are requested every racing season to submit applications for permits to import either a "privately purchased horse" ("PP") or a "privately purchased Griffin" ("PPG") to Hong Kong. A "PP" is a previously raced horse while a "PPG" is one which is imported to Hong Kong that has never raced. The Club also organizes an annual auction of International Sales Griffin (ISG). Each imported horse is then allocated a Rating accordingly under the following criteria.

Ratings for imports are as follows:

Privately Purchased Horse (PP) that has raced overseas
Ratings are allocated based on the Hong Kong Jockey Club Handicappers' assessment of overseas performance.

Privately Purchased Griffins (PPG) and International Sale Griffins (ISG) that have never raced prior to import

a. PPG and ISG who are 3 years old on 31st December in the season for which the permit is granted will be allocated a rating of 57 (Northern Hemisphere-bred) or 52 (Southern Hemisphere-bred) on arrival.

b. PPG and ISG who are 2 years old on 31st December in the season for which the permit is granted will race in Griffin races, which will be run on weight-for-age terms. Winners of one race will carry a 7lb penalty. PPG and ISG which run in Griffin races are allocated a rating subject to the following conditions:

- Winners of two races will be allocated a rating immediately.
- After 1st May, a trainer has the option to request that a rating be allocated to a winner of one race.
- No horse allocated a rating is eligible for Griffin races unless otherwise specified in the conditions of the race.
- The initial minimum rating allocated to a Griffin winner will be 60 for Northern Hemisphere 3-year-olds and 55 for Southern Hemisphere 2-year-olds.
- All other Griffins will be allocated a rating at the end of the season.
- The maximum initial rating for a maiden Griffin at the end of the season that has been placed second, third or fourth will be 60, and that for a raced but unplaced Griffin will be 57.
- Griffins which are unraced at the end of the season will be allocated an initial rating of 57 (Northern Hemisphere-bred) or 52 (Southern Hemisphere-bred).

vi. Regulation

Horses can potentially remain in training and racing until compulsory retirement at 10 years of age. This age limit was 11 years prior to the 1996 season.

Premature compulsory retirement may also occur. Current Rules of Racing require compulsory retirement following three officially recorded episodes of epistaxis (bleeding from the nostrils associated with Exercise Induced Pulmonary Haemorrhage, EIPH) or three episodes of heart irregularity during the racing career.

Horses can be retired voluntarily at any time during the racing career due to injuries with a poor prognosis or for other reasons. Retired racehorses are assessed by a compulsory veterinary inspection for suitability for local riding schools, for export or when an application is made for a replacement horse. All import and export of racehorses is licensed by the Jockey Club. This policy maintains a controlled racing population in Hong Kong.

The Hong Kong Jockey Club has designed and implemented many systems and procedures making continual efforts to optimise the welfare of the racehorses in Hong Kong.

The horse racing industry is of great importance to Hong Kong. In order to prevent the introduction of equine diseases, import of horses to Hong Kong is subject to stringent quarantine control policy and protocols by the Hong Kong Government Agriculture, Fisheries and Conservation Department and the Hong Kong Jockey Club.

Upon arrival the horses are required to undergo post-arrival quarantine under approved veterinary supervision. Currently such quarantine facilities are only available at the Hong Kong Jockey Club.

The authority of the Club Veterinary Surgeons is to provide veterinary services and investigate disease is defined by Rule 46 of the HKJC Rules of Racing:

"The Veterinary Officer and the Veterinary Surgeon have the authority to carry out any veterinary procedures which in their professional opinion are necessary either in the interests of the individual horse, or of overall equine health, or of racing in general."

The Club has a comprehensive injury minimization system that has been implemented and continually fine-tuned over the past twenty five years.

The important components of the system include:

- Intensive well maintained training and racing surfaces with veterinary and tracks management liaison
- Comprehensive racing and training injury reporting systems

- Conservative and robustly enforced medication and prohibited substance control policies with horse-in-training random sampling program for unauthorized medication
- World class veterinary clinical services and veterinary management information system
- Sensible race-day farriery policies
- Strong veterinary regulation system
- Comprehensive veterinary suitability to race management systems including official veterinary examinations for clearance to race after injury, illness or poor racing performances and pre-race veterinary inspections
- Regulatory access to all horses' veterinary medical records
- Track-work monitoring systems with data accessible via the Club's website
- Pre-importation veterinary examinations for suitability for use as a racehorse

vii. Veterinary Regulation

In 2002, the Club management completed a function review of the mixed clinical and regulatory roles of the Club Veterinary Surgeons and made recommendation to separate roles and responsibilities of regulatory and clinical functions. The separation aims to remove the perceived or potential conflict of interest caused by the same Veterinary Surgeon performing both clinical and regulatory functions. In addition the separate regulatory and clinical departments can further strengthen integrity of racing and raise the quality of Club veterinary clinical services. Department of Veterinary Clinical Services (DVCS) and Department of Veterinary Regulation and International Liaison (DVR&IL) were officially established in 2003 with Veterinary Surgeons of DVCS employed by the Club to provide clinical veterinary services and Veterinary Officers of DVR&IL employed by the Club to provide regulatory veterinary duties.

i. The DVR&IL works closely with Racing Control, the Racing Laboratory and the DVCS to perform the following key regulatory functions:

- Officiating at race meetings and barrier trials and performing official veterinary examinations.
- Reviewing racehorses' veterinary histories and track work records and performing pre-race veterinary inspections for suitability to race.

- Performing pre-race veterinary inspections.
- Advising the Stipendiary Stewards and relevant racing officials on veterinary health medication, prohibited substances and horse welfare issues.
- Managing veterinary aspects of international racing.
- Liaison with government veterinary authorities on horse import and export matters, quarantine and disease control.

viii. Veterinary Clinical care

The Department of Veterinary Clinical Services (DVCS) maintains the health and welfare of all horses in Hong Kong. Apart from caring for 1,200 thoroughbred horses in race training at the Club's Sha Tin racecourse, the department also looks after 600 retired racehorses, ponies and other horses involved in equestrian activities in eleven riding establishments throughout the territory. The department has a team of 10 clinicians and a team of over 30 support staff including veterinary assistants, clinical laboratory technicians, farriers and administrative staff. DVCS also provides clinical veterinary and farriery cover at all race meetings, assists with the formulation and implementation of veterinary regulatory procedures and provides information and advice on clinical matters to relevant parties.

III. Hong Kong Jockey Club Databases

The Racing Information System (RIS) is critical to the Club's business systems (Figure 4). It records and stores details of owners, horses, trainers, jockeys and races data in over 404 Microsoft Access Tables and 3710 data fields including racing records, ownership, trainers and earnings. The oldest records date back to 1972. Data and information are disseminated via system interfaces to both internal and external systems, including a trackwork database (Figure 5).

Figure 4 – An overview information flow diagram of the system interface of the Racing Information System (RIS) of the Hong Kong Jockey Club

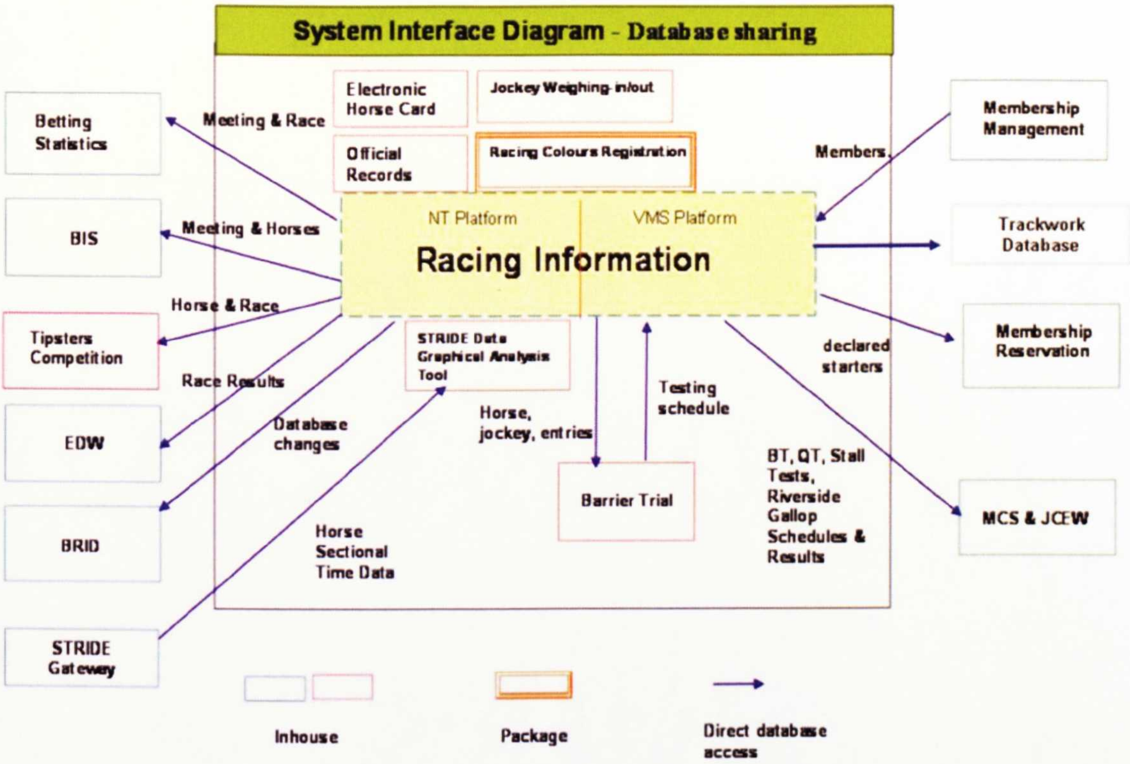
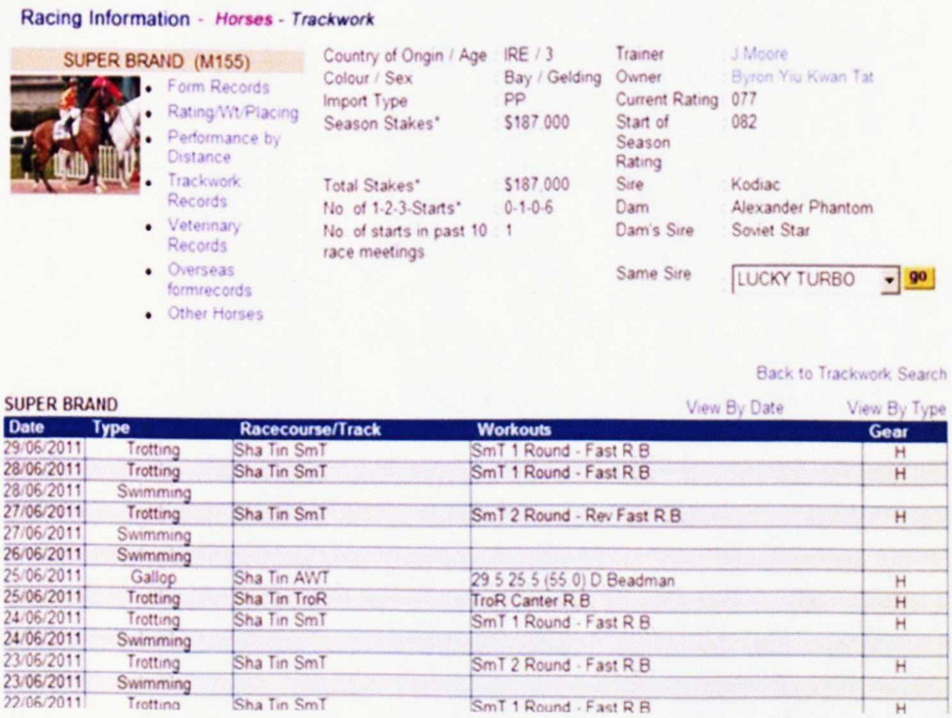


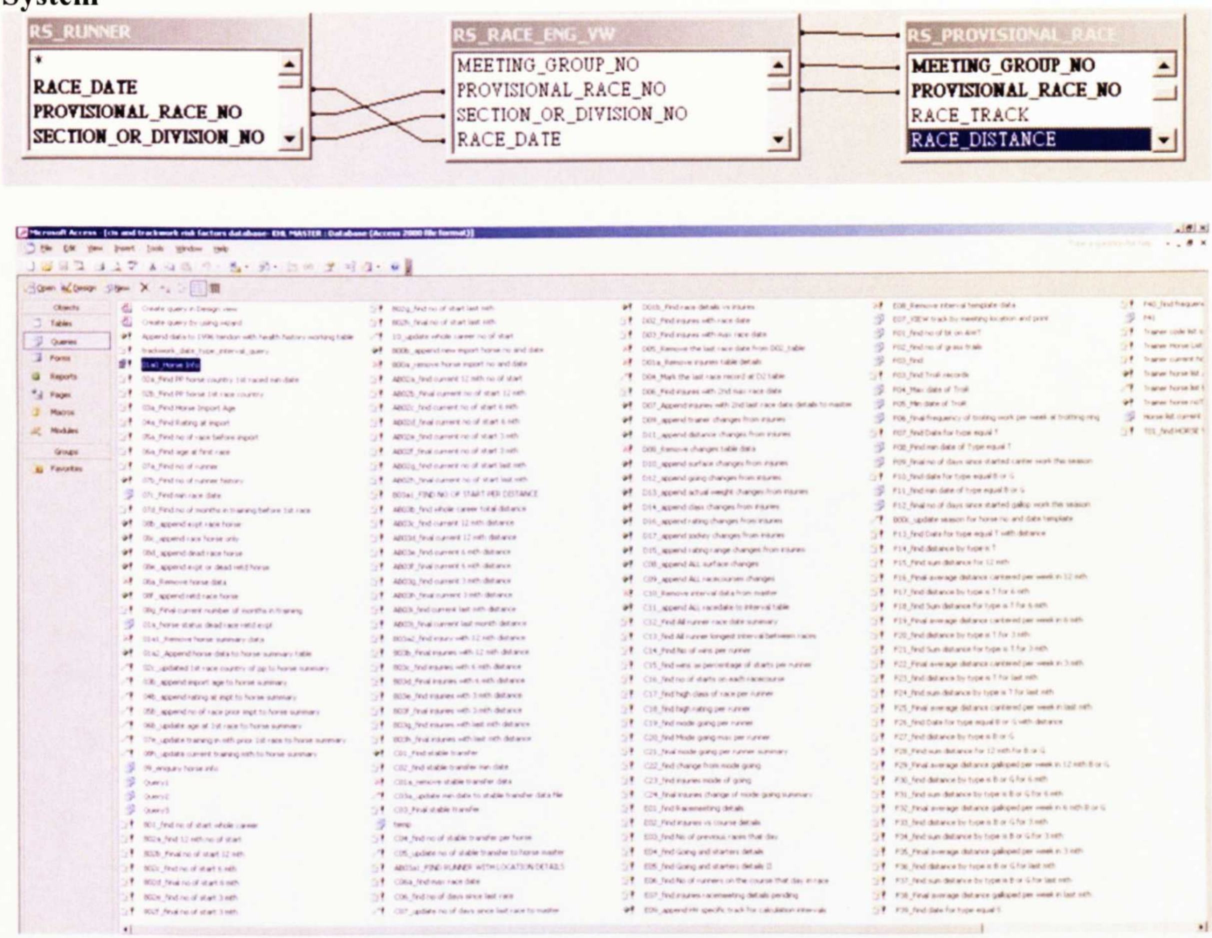
Figure 5- Turftimers Hong Kong Trackwork Database illustrating an example of the trackwork records of a racehorse in Hong Kong.



Date	Type	Racecourse/Track	Workouts	Gear
29/06/2011	Trotting	Sha Tin SmT	SmT 1 Round - Fast R.B.	H
28/06/2011	Trotting	Sha Tin SmT	SmT 1 Round - Fast R.B.	H
28/06/2011	Swimming			
27/06/2011	Trotting	Sha Tin SmT	SmT 2 Round - Rev Fast R.B.	H
27/06/2011	Swimming			
26/06/2011	Swimming			
25/06/2011	Gallop	Sha Tin AWT	29.5 25.5 (55.0) D Beadman	H
25/06/2011	Trotting	Sha Tin TroR	TroR Canter R.B.	H
24/06/2011	Trotting	Sha Tin SmT	SmT 1 Round - Fast R.B.	H
24/06/2011	Swimming			
23/06/2011	Trotting	Sha Tin SmT	SmT 2 Round - Fast R.B.	H
23/06/2011	Swimming			
22/06/2011	Trotting	Sha Tin SmT	SmT 1 Round - Fast R.B.	H

The system architecture is managed by the HKJC IT Division. Information retrieval is achieved by setting Structured Query Language (SQL) to query, update, and manage relational databases in the ACCESS tables of the RIS system. In addition Select Query function in Microsoft ACCESS can be formulated to group records and calculate sums, counts, averages, and other types of totals (Figure 6).

Figure 6- Example of Microsoft ACCESS database Query list of the Racing Information System



A summary list of racing history, horse details and training variables for investigation via Microsoft Access Query Template methodology by accessing Racing Information System and Trackwork Databases is outlined in Tables 1 and 2.

Table 1 - Summary List of racing history, horse detail and training variables for investigation via Microsoft Access Query methodology development by accessing Racing Information System and Trackwork Databases

Previous racing history and horse details	Training details
Injuries table template ACCESS TABLE is the master table for horse number and date with input of EXTERNAL data to this file. Just need to overwrite to update from importing data files. Query B00a to B00c to update all data to horse no and template TABLE Once completed Queries D01a and D01b, the following queries can be run individually without these two queries. Horse details: Queries 01a0 to 08h+B01+10 (Marco 01_summarized horse info OR Forms Run updated Horse Information) - > Table 01_Horse summary information (Marco 02_Enquiry horse info)- for individual or overall horse database search • Country in which horse was bred - Country of origns – RS_Horse_VW_VE • Country of Export -Exported_Country - RS_Horse_VW_VE • Country where first raced (PP only) – Country_Code - RS_O_Performance • Sire - RS_Horse_VW_VE • Dam - RS_Horse_VW_VE • Gender (colt, stallion, gelding, filly, mare) – Horse_Sex - RS_Horse_VW_VE • Age at import – Import_Age - RS_Horse_Others • Import status (PP/ PPG) -Horse_ Import_Type- RS_Horse_VW_VE • Rating at import – Horse_Initial_Rating – RS_Private_Pur_Horse • No. of races prior to import – RS_O_Performance • Age at first race – Horse_Age – RS_O_Performance • Current Age – Current_Status_Age - RS_Horse_VW_VE • Number of months in training before first race – [Race_date (Min) – (RS_Runner + RS_Runner_History) - Horse_Import_Date – RS_Horse_VW_VE]/30 • Current number of months in training – (Today – Horse_Import_Date – RS_Horse_VW_VE)/30 • Current HKJC rating – Horse_Current_Rating – RS_Horse_VW_VE • Trainer- Trainer_Code (in injury report form database for date after April 2004; for date before April 2004- Type=S, Code=TRANS –	Training regimen: Based on updated horse no and date template from injuries table template TABLE Query F01 -> Table F01 (result) • Number of barrier trials on all weather tracks – Count of Type=B+RC=ST+Trace Track=AWT in Trackwork Database Query F02; then Query F02a -> Table F02a (HV) Query F02b -> Table F02b (ST) Query F02c -> Table F02c (Total HV + ST) • Number of grass trials – Count of Type=B+Trace Track=Turf+ RC=HV and ST – Trackwork database • Distance walked per week on tarmac – N/A Queries F03 and F06 -> Table F06 (result) • Frequency of trotting work per week at trotting ring – only frequency – Count of Trace Track "TroR" divided by [Number of days (Max_date "TroR" -Min_Date "TroR")/ 7] in Trackwork database Queries F07 and F09 -> Table F09 (result) • Number of days since started canter work this season – Present Date (Injury Date) - Min Date and Type=T in Trackwork Database (Min date calculation: Make table of min date of Type=T, Min date of the made table) Queries F52 and F56 -> Table F56 (result) • Number of days since started canter work for whole career Queries F10 and F12 -> Table F12 (result) – this season • Number of days since started gallop work this season - Present Date (Injury Date) - Min Date of Type=B or G in Trackwork Database (Min date calculation: Make table of min date of Type=B or G, Min date of the made table) Queries F52, F58a and F60 -> Table F60 (result) • Number of days since started gallop work for

RS_Treatment_Transaction with Treatment_comment_1(set period) Racing intensity: Based on current day query: Queries AB02a to AB02h and corresponding Tables (last month, 3, 6, and 12months); Queries B01 and "10" to update whole career number of starts -> Table 01_horse summary info Based on a given previous date injury query: First to remove (**Query B00a**) and import data from **Injuries table template**; then update (**Query B00b -> horse no and date template TABLE**); followed by B00c (update Racing Season) Query B02a to B02h -> corresponding Tables: • Number of starts in last month, 3 months, 6 months, 12 months, whole career – Race_Date – RS_Runner+RS_Runner_History (set criteria period) Based on current date query: Query B03a1 -> Table AB03a Query E01 -> Table E01 Query AB03a1 -> Table AB03a1 Queries AB03b to AB03j -> corresponding Tables Based on previous date injury query : Query B03a2 to B03h -> corresponding Tables • Total distance raced in last month, 3 months, 6 months, 12 months, whole career - RS_Distance – RS_Provisional_Race+RS_Race_Eng_VW+RS_Runner+RS_Runner_History (set criteria period) **For racing injuries since last race:** (create a temporary table to search for max date in Access : to be followed by extraction and re-calculation of max date to identify the second last date) *Queries D01a to D07 **Based on current date query (for RACE status): Queries C06a to C07 -> Table 01_Horse summary information** **Based on previous date query (import to Table horse no and date template)** Queries *->D08a1 to D08a2 -> Forms Form1 (Generate Table- History with intervals (Desc)) -> Query D08a3 -> Table D08a3 • Number of days – Today – Race_Date (Max) – RS_Runner **Queries *->D08 and D09a -> Forms Form1- Trackwork Changes History)-> Query D09b->Table D09b**	whole career Queries F13 to F16 -> Table F16 (result) – 12 months Queries F13, F17 to F19 -> Table F19 (result) – 6 months Queries F13, F20 to F22 -> Table F22 (result) – 3 months Queries F13, F23 to F25 -> Table F25 (result) – Last month • Average distance cantered per week – Type=T and Trace Track=SmT or AWT Queries F26 to F29 -> Table F29 (result) – 12 months Queries F26, F30 to F32 -> Table F32 (result) – 6 months Queries F26, F33 to F35 -> Table F35 (result) – 3 months Queries F26, F36 to F38 -> Table F38 (result) – Last month • Average distance galloped per week Queries F52 to F53 -> Table 53 (result) – whole career Queries F66 to F67 -> Table 67 (result) –12 months Queries F68 to F69 -> Table 69 (result) – 6 months Queries F70 to F71 -> Table 71 (result) – 3 months Queries F72 to F73 -> Table 73 (result) – Last month • Total distance cantered this season (Distance per canter work updated in Trackwork database) Queries F52 and F57 -> Table 57 (result) – whole career Queries F74 to F75 -> Table 75 (result) –12 months Queries F76 to F77 -> Table 77 (result) – 6 months Queries F78 to F79 -> Table 79 (result) – 3 months Queries F80 to F81 -> Table 81 (result) – Last month • Total distance galloped this season (Distance per gallop work updated in Trackwork database) Queries F39 to F42 -> Table F42 (result) – Last month Queries F39, F43 to F45 -> Table F45 (result) – 3 months Queries F39, F46 to F48 -> Table F48 (result) – 6 months Queries F39, F49 to F51 -> Table F51 (result) – 12 months • Use of swimming facilities (frequency per week)

• Change in Trainer (i.e. stable transfer) – Type=S, Code=TRANS – RS_Treatment_Transaction with Treatment_comment_1(set period) **Based on current date query:** Query D08 -> Query C08a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query C08b->Table C08b (for results) ***Based on previous Injury date:*** Queries *-> D08-> Query D10a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D10b ->Table D10b (for results) • Change in racing surface (turf/ all weather track) Race_Track – RS_Provisional_Race **Based on previous Injury date:** Queries *-> (to append from horse no and date template)-> Query D08-> Query D11a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D11b ->Table D11b (for results) • Change in distance –Race_Distance – RS_Provisional_Race **Based on previous Injury date:** Queries *-> D08-> Query D12a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D12b->Table D12b (for results) • Change in going –Race_Going – RS_Race_Eng_VW **Based on previous Injury date:** Queries *-> -> D08 ->Query D13a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D13b->Table D13b (for results) • Change in weight carried – Actual_Weight – RS_Runner (first search for max date then remove from list and search the second max date) **Based on previous Injury date:** Queries *-> D08 -> Query D14a-> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D14b->Table D14b (for results) • Change in class of race – Race_Class – RS_Provisoinal_Race **Based on previous Injury date:** Queries *-> D08 ->Query D15a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D15b->Table D15b (for results) • Change in rating range – Rating range- RS_Provisional Race **Based on previous Injury date:** Queries *-> D08 ->-> Query D16a -> Forms Form1 (choose Generate Table- Trackwork changes history) ->	Query F52, F65 -> Table F65 (result) • Total number of swimming for whole career • Use of water treadmills (frequency per week) • Number of 1800 M gallops- Workout Description "Back Straight" in Trackwork Data Database • Number of Riverside gallops – Workout Description "Riverside Gallop" in Trackwork Data Database

Query D16b->Table D16b(for results)

- Change in runner rating – Runner_Rating – RS_Runner

Based on previous Injury date:
Queries *-> D08 ->-> Query D17a -> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query D17b->Table D17b (for results)

- Change in Jockey – Jockey_Code – RS_Runner

Over whole career:

Based on current date query:
Queries C01a to C05 -> Table 01_Horse summary information
Number of Trainer stable transfers – use count function from extraction of – Type=S, Code=TRANS – RS_Treatment_Transaction with Treatment_comment_1

- Query D08->C08a->Forms Form1 (choose Generate Table- Trackwork changes history)->Query C08b->Table C08b (for results)
- Number of changes of racing surface - Race_Track – RS_Provisional_Race+RS_Runner,+RS_Race_Eng_VW – ?module to design formulate

Query D08 -> Query C09a> Forms Form1 (choose Generate Table- Trackwork changes history) -> Query C09b->Table C09b (for results)

- **Number of changes of racecourses** – Meeting_Location – RS_Meeting+ RS_Provisional_Race+RS_Runner,+RS_Race_Eng_VW

Queries C10 to C11a -> Forms Form1 (choose Generate Table- History with intervals (Des) -> Query C11b->Table C11b(result)

- **Race date intervals**

Queries C10 to C11a -> Forms Form1 (choose Generate Table- History with intervals (Des) -> Queries C12 to C13 -> Table C13 for results

- Longest interval between races – Race_Date – RS_Runner+Date sorting interval.mdb (sorted by max base on interval per horse)

Query C14 -> Table C14 (result)

- Number of wins – No_of_1^{st}_PLA+No_of_1^{st}_DH – RS_Horse_Statistics

QueriesC14 ->C15 -> Table C15 (result)

- Wins as percentage of starts – count no. of wins divided by Total_starts (Set 9999) – RS_Horse_Statistics

Query C16 -> Table C16 (result)

- Number of starts on each racecourse (Shatin and

Happy Valley) – no. of count of ST and HV - Meeting_Location – RS_Meeting+ RS_Provisional_Race+RS_Runner,+RS_Race_Eng _VW Query C17 -> Table C17 (result) • Highest class of race – Max of Race_Class – RS_Provisoinal_Race Query C18 -> Table C18 (result) • Highest rating – Max of Runner_Rating – RS_Runner Queries C19 to C21 -> Table C21 (result) • Mode going (most frequent going raced on) - Race_Going – RS_Race_Eng_VW (followed by group and count of each going to search for max type) In current race: Based on TABLE horse no and date template (for injury list) Queries C19 to C24 -> Table C24 (result) • Change from mode going Race_Going – RS_Race_Eng_VW (followed by group and count of each going to search for max type and max race date going – harder or softer) Table C22 (result) • Use of blinkers, visors, tongue ties – Blinkers – RS_Runner • Weight carried - Actual_Weight – RS_Runner • Field size – No_of_starters – RS_Race_Eng_VW	

Table 2- Summary List of race and course level variables for investigation through Microsoft ACCESS Queries

Variables specific to the study race	Variables specific to the course
Race details: Based on TABLE horse no and date template (for injury list) Query C22 -> Table C22 (result) • Start time – Post_Time – RS_Race_Eng_VW • Distance (m) – Race_Distance – RS_Provisional_Race • Number of runners – No_of_Starters -	Course details: Queries E02 and E03 -> Table E03 (result) • Number of previous races that day. – Race_No – RS_Runner-1 Queries E01 to E02, E04 to E06 -> Table E06 (result) • Number of runners on the course that day in races before the study race – No_of_Starters - RS_Race_Eng_VW+Race_Track – RS_Provisional_Race (Group by Race_Track+No_of_starter of each previous race of

RS_Race_Eng_VW • Class of race (Rating class) – Race_Class+Rating_range – RS_Provisional_Race • Winners prize money – Prize_money_01 – RS_Race_Eng_VW • Speed of race (race time) – Race_Time – RS_Race_Eng_VW • Number of seconds per 400m (average sectional timing) - Section_Time_01 to 06 – RS_Race_Eng_VW Conditions of entry into the race: • Horse restrictions (N/A) • Jockey restrictions (N/A) • Query C22 -> Table C22 • Apprentice or licensed jockeys only – Jockey_Type+Jockey_Code – RS_Runner (Jockey Type: A=Appendice; L=Local; V=Visiting Jockey (Int'l Race); C=Club, R=Stable Retained)	same race track type) Query E02 -> Table E02 (result) • Going during the study race - Race_Going +Race_No – RS_Race_Eng_VW Query E01->E04c->Forms Form1 (choose Racecourse details summary)->Query E10 -> Table E10 (result) • Turf races: Firm, Good to Firm, Good, Good to Yielding, Yielding, Yielding to Soft, Soft, Heavy – Race_Track (RS_Provisional_Race) +Race_Going (RS_Race_Eng_VW) • All-weather races: Fast, Good, Wet fast, Wet, Slow, Heavy, Normal Watering, Rain Affected. **Queries E01-> aE04c -> Forms Form1 (choose Racecourse details summary) -> Table E08 (result)** • Number of days since the previous race meeting at the course - Meeting_Location – RS_Meeting. –max of Race_Date – second max of Race_Date of same meeting_location (ST or HV) • Going during the previous race meeting at the course - Race_Going - RS_Race_Eng_VW • Change in going between current and previous race meeting. - Race_Going - RS_Race_Eng_VW max date and second max date to compare • Change in running course (for example, Course A, B, C, C+3) between current and previous race meeting – Race_Course _ RS_Meeting max date and second max date to compare

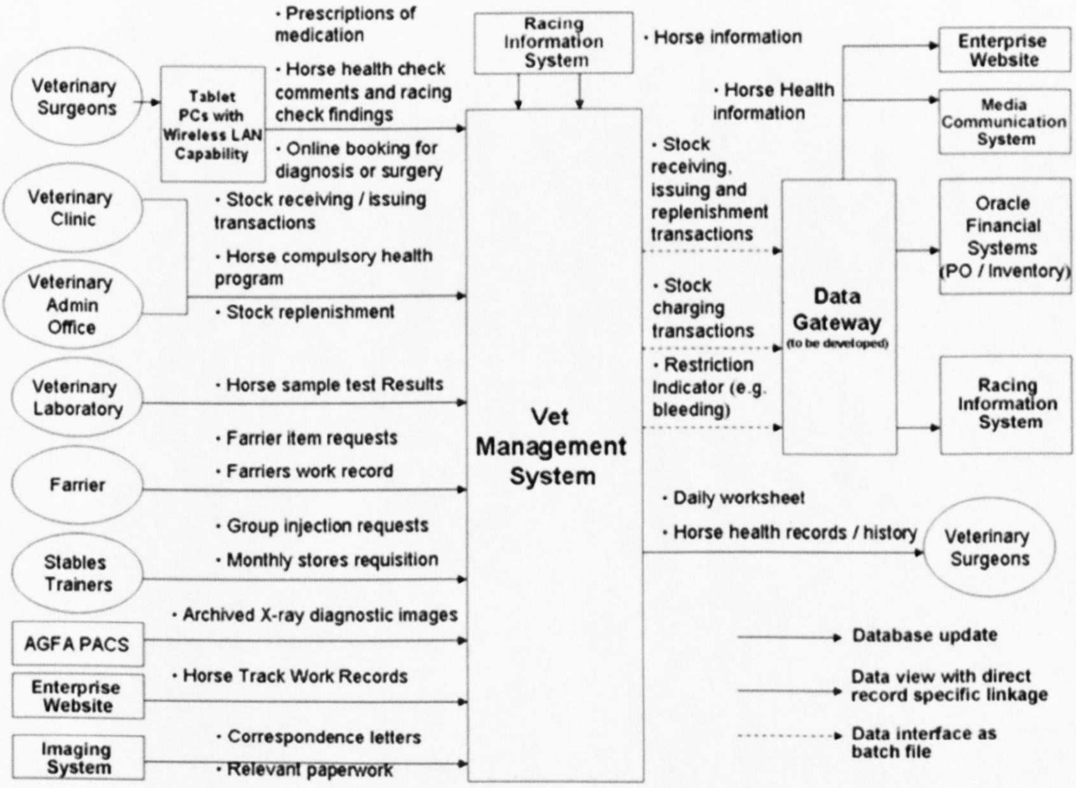
Veterinary Management Information System (VMIS)

The Hong Kong Jockey Club's Veterinary Management Information System (VMIS), a system jointly developed by the Club's Information Technology Division and the Department of Veterinary Clinical Services. It was developed in 2003 and launched in 2005. The Club has won one of the 2007 CIO Awards on the invention of VMIS- an honour given to the top five organisations across Asia that have successfully applied groundbreaking innovation in the strategic use of information technology (**http://www.hkjc.com/english/corporate/corp_news_item.asp?in_file=/english/news/news_2007032815613.htm**). The Club was the only organisation from Hong Kong to win this prestigious award. The joint efforts of Information Technology Division and the Department of Veterinary Clinical Services benchmark the cross-departmental teamwork that has brought the Club success in the prestigious CIO Award. The key developers of the VMIS system included Mr Sunny Lee, Executive Director of Information Technology; Mr Leo Cheung, IT

Solutions and Development Manager (Racing), Dr Christopher Riggs, Head of Veterinary Clinical Services and Dr Kenneth Lam, Veterinary Officer .

The VMIS is an all-in-one veterinary management information system which provides veterinary surgeons with real-time, on-the-spot horse health and medical information through the use of tablet computers, wireless Local Area Network (LAN), connections and integration with X-ray, ultrasound, document imaging and inventory systems (Figure 7). The wireless network on which the system operates also provides one of the biggest indoor and outdoor network coverage in Hong Kong.

Figure 7 - Veterinary Management Information System (VMIS) Overview Diagram



VMIS operates on a wireless network with coverage extending across a wide geographic area of Sha Tin Racecourse from the Stables Complex to the Equine Hospital.

The system leverages proven technologies including medical digital radiography imaging, digital document management, web-based applications and wireless technology. This enables Veterinary Surgeons to access and manage horse health records, medication and statistical information in real time on a homogenous platform at their place of work (Figure 8). The system facilitates the upkeep of records for these horses, arguably one of the Club's most critical and valuable assets, in the most efficient and effective manner.

Figure 8- Veterinary surgeons Dr Christopher Riggs and Dr Kenneth Lam access X-ray images and medical records in the stables area through wireless Local Area Network.

VMIS Project Significance

The project is significant to the Club because it has enabled the Veterinary Department to provide high quality customer service to Horse Trainers and Owners by allowing online access to all related horse information in real-time.

a) Successful implementation of the project demanded a flexible system architecture, supported by regular joint application development sessions (JADS) and complex integration of technologies from different suppliers and service providers. The system integrates AGFA Digital Picture Archiving and Communication System (PACS), Vitova (HK) Document Management System, in-house developed web-based applications with an extensive wireless network implementation – equipment being provided by Fujitsu Computer and Cisco Systems plus network system integration (SI) by Hewlett-Packard Hong Kong SAR Limited.

b) VMIS is the first integrated Veterinary Management Information System, adopting both indoor and outdoor wireless network technology, in the Asia Pacific region.

c) This project has successfully migrated 25 years' of clinical record databases from the earlier 1980's generation of IT system.'

VMIS is an integrated system that facilitates capturing, processing and disseminating of Veterinary management information.

The system has enabled Veterinary Surgeons to retrieve or update horse health information and raise Stock Requisitions (SR) for prescription of medication to the store by using portable tablet computers via a wireless network installed in areas covering all stables and Veterinary clinics in the Sha Tin Racecourse..

Veterinary Surgeons can also view and make bookings of diagnosis and surgery facilities. Health and treatment records of horses are also updated and disseminated to the Veterinary Administration Office for further processing before transferring to the Club's Oracle Financial systems. Other management information (for example, AGFA PACS), statistics and reports that support management decisions can be generated from the system.

In summary, the objectives of the systems are to:

• Support veterinary surgeons to deliver world class clinical services by providing them with up-to-date and on-the-spot horse health and race related information either during diagnosis or operations, whether in the Stables Complex or in the Equine Hospital, via real-time access through wireless networks without geographic limitation.

- Minimise the physical paper flow between stables, veterinary surgeons, veterinary clinical staff and the Veterinary Administration Office.
- Minimise the administration workload through automation of bookings and scheduling programs, and reduce overall processing time.
- Eliminate data input time lag, data duplication and discrepancy by integrating the stand-alone inventory control system with the new Veterinary Management Information System.
- Integrate existing digital diagnostic imaging system (AGFA PACS) and Veterinary Document Information System (Vitova solution).
- Support future expandability and scalability of new veterinary functions in various areas including research and planning.
- Maintain detailed clinical records and facilitate thorough data analysis to achieve;
- Enable critical review of business objectives;
- Prepare information for research purposes;
- Support legal reports on medical matters.

The Hong Kong Jockey Club collects, stores and maintains a large volume of data for all horses trained in Hong Kong. Data are collected from about 1200 horses housed and trained at the Sha Tin racecourse. A wide range of variables are included in this dataset e.g. track parameters, environment, training and racing performance, general health, and veterinary management. This is probably the world's most complete dataset on racehorse health and performance. A wide range of information established in a database in the early 1970s at the Hong Kong Jockey Club, including records of the health and racing performance of more than 6000 horses provided an opportunity for a retrospective analysis of the pattern of injuries and retirement from racing of thoroughbred racehorses at the Hong Kong Jockey Club.

IV. Importance of horse longevity (wastage)

Generally

Longevity is of economic importance in the Thoroughbred racing industry because of expenses and time invested in breeding and training. In spite of the high costs invested in racing horses, there have been only a limited number of studies of risk factors that can affect length of racing careers of Thoroughbreds (Jeffcott et al. 1982; Rossdale et al. 1985; Bailey et al. 1997; Wilsher et al. 2006).

Knowledge of factors that influence longevity is crucial for optimization of the training methods aiming at reducing wastage which refers to losses that occur at racing industry. An understanding of the role of some factors may help owners, trainers and other equine professionals to optimize the performance of the horses under their care.

In Hong Kong

i. Business

On 1st July 2004 the Hong Kong Standard Newspaper on reported "Punters thrown by horses" through the public consultation of "Why did our customers bet less?"

The Club conducted a public survey of 1500 punters at Off-Course Betting Centres and revealed that 22% attributed the decrease in betting turnover to the high turnover of horses. The respondents indicated that they were "Unfamiliar with new horses." Other reasons for causes of reduction in betting turnover are listed below **(Table 3)**:

- 57% respondents indicated "Poor economy/ less spare money"
- 35% respondents indicated "Inconsistent horse performance (e.g. injuries)"
- 16% respondents indicated "Too many lower class races"

Table 3 (Page 1)- Survey conducted by Hong Kong Jockey Club on 1,500 punters at the Off-course Betting Centres (ODBC) in June 2004

Reasons for betting less on HK horse races

Poor economy, perceived low chance of winning, unattractive odds, long working hours as most relevant to betting less on horse races

Base: Those who said they had bet less this season (% saying reason very relevant *)	OCBB customers %
Poor economy / less spare money	**57**
Chance of winning is low / difficult to win	**39**
Odds / dividends of winning horses too low / unattractive	**26**
Extended working hours	**23**
Less time available to do analysis	18
Closure of OCBB	17
Bet / gamble in other forms more often	16
Spend more time with family	15
Inconvenient betting services	12
Spend more time on other leisure activities / entertainment	7
Need to travel more to Mainland China	4

Overall, abou 20% or more the responde considered these factors very relevant their betting less on horse races this season.

Table 3 (Page 2)- Survey Result (Cont.)

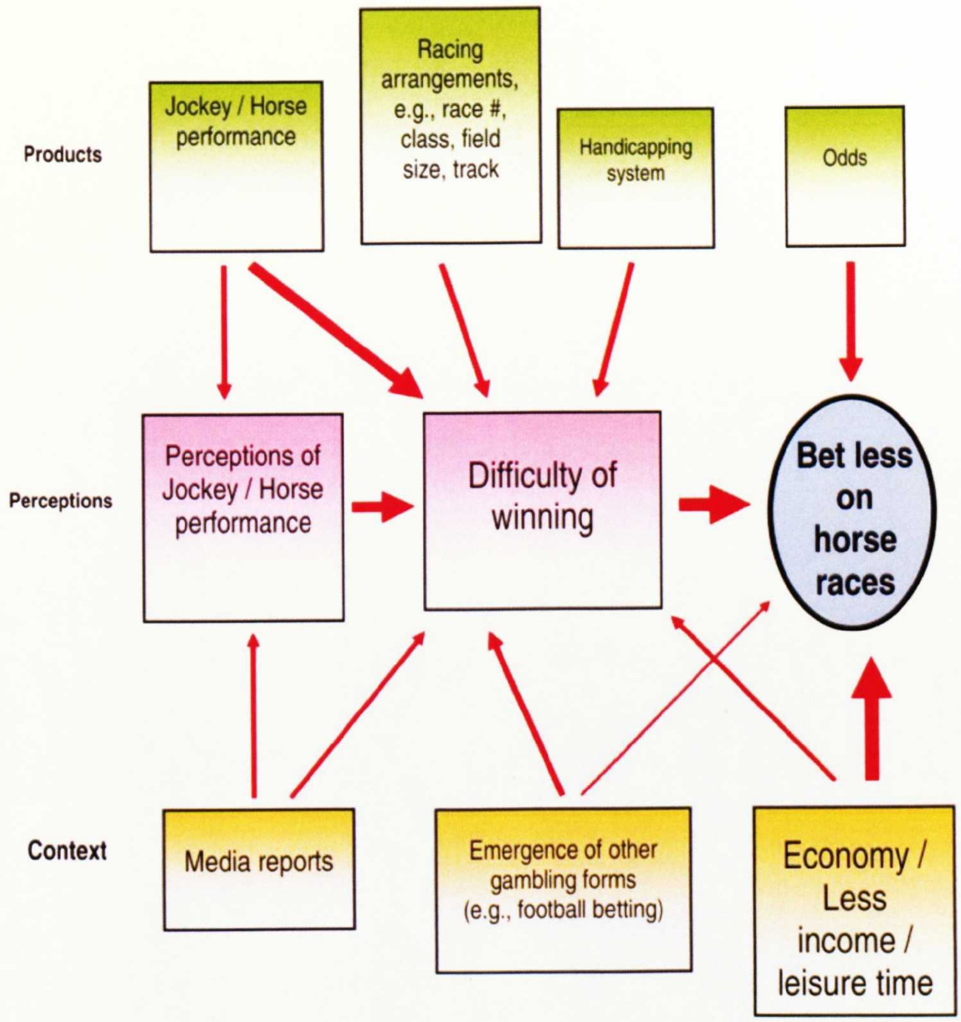
Poor jockey performance, losses of top favourites, inconsistent horse performance, frequent jockey changes most relevant to perceived low chance of winning

Base: Those who said they had bet less this season (Prompted reasons - % saying reason very relevant **)	OCBB customers %
Jockeys do not try their best / perform consistentlv	**43**
Top favourite horses lose too often	**37**
Inconsistent horse performance	**35**
Frequent changes of jockeys within a season	**23**
Too many races with non-performing horses	23
Unfamiliar with new horses	22
Last minute odds fluctuations too fast to follow	16
Too competitive races	16
Too many lower class races	16
Too many horses in a race	13
Inaccurate tips provided by tipsters	13
Too much betting/racing information / Complicated information	13
Too many races on a raceday	8

Overall, about 20% or more of the respondents considered these reasons as very relevant to difficulty of winning.

* 5-point rating scale: 1 = not relevant at all ... 5 = very relevant

Table 3 (Page 3)- Changing Perceptions of Horse Racing



Appendix 2

11th International Symposium on Veterinary Epidemiology and Economics (ISVEE XI) 2006 Australia Abstract

Theme 5 Evaluation of Animal Disease. Surveillance. Risk Analysis.
Economics. Prioritisation

Equine Research In Hong Kong: Classification Of Free-text Clinical Records Using Content Analysis

LAM Kenneth, PARKIN Tim, RIGGS Chris and MORGAN Kenton

Introduction

The database at the Hong Kong Jockey Club, established in the early 1970s, holds records for over 6000 horses. This includes horse health and racing performance. However, the reasons for retirement are recorded as free text. Here we use context analysis, a method more frequently used in social sciences, to assess the retirement pattern of Thoroughbred racehorses in Hong Kong.

Materials and Methods

The content analysis software package- WordStat and SimStat, (Provalis Research, Quebec, Canada) was used to provide a replicable technique for compressing many words, ungrammatical phrases and unstandardized abbreviations of clinical text into categories based on explicit rules of coding. This technique enables a large volume of records (in the range of thousands) to be sorted rapidly in a systematic manner with high accuracy and reliability.

Results

Automated categorization based on a user-defined dictionary achieved a success rate of over 95% in classification of the free-text clinical records. The reasons for retirement of 3727 Thoroughbred racehorses over a 12-year period (1992-2004) were classified in to 21 groups. The system demonstrated inherent standardisation amongst words and phrases used for clinical description, including patterns of related clinical signs.

Discussion

The use of context analysis to categorise "free text" clinical records offers a rapid and reliable alternative to coding systems in clinical data recording. It allows clinicians the opportunity to continue to use free text to describe disease. This offers more flexibility to discover new clinical syndromes as well as to develop a veterinary lexicon for standardization of data entry.

Appendix 3

11 th International Symposium on Veterinary Epidemiology and Economics (ISVEE XI) 2006 Australia Abstract

Theme 2 Investigation of Disease Distribution and Determinants• Companion Animal

Investigation of Factors Contributing to Retirement of Racehorses from Tendon Injuries in Hong Kong

LAM Kenneth, PARKIN Tim, RIGGS Chris and MORGAN Kenton

Introduction

The aim of this study is to reduce financial loss associated with the premature retirement of Thoroughbred racehorses at the Hong Kong Jockey Club (HKJC). Content analysis of over 3700 clinical records in the 12-year period (1992-2004) has identified tendon injuries as a major problem accounting for over 20% (512/ 2338) of reasons for retirement with a veterinary diagnosis.

Materials and Methods

A case control study was conducted to identify the risk factors for tendon injuries. A major problem was identification of the date on which the injury occurred. A case was defined as a horse retired because of tendon injury, in which the last exercise was at gallop pace. 175 cases and 525 matched controls were selected. Controls were uninjured horses that galloped on the same day. Factors related to training, racing and medical history were examined and analysed using conditional logistic regression (EGRET).

Results

The study demonstrates the difficulty in identifying incident cases using retrospective records where injury may be difficult to identify, aggravated by further exercise and recurrent. Different case definitions have been used to overcome this but these require certain assumptions to be made. The influence of this on risk factors identified will be presented.

Discussion

In this study the unique training records in the HKJC have been used to identify the risk factors for retirement from racing because of tendon injury. The studies have also identified areas where data recording can be improved and have informed prospective studies.

Appendix 4

2006 British Equine Veterinary Association CONGRESS, BIRMINGHAM, UK

Clinical Research Abstract

Investigation Of Factors Contributing To Retirement of Racehorses from Tendon Injuries In Hong Kong

Author(s): Lam K., Parkin T., Riggs C., Morgan K.

Address of Department, Institution or Practice where the study was performed: Department of Veterinary Clinical Services, Hong Kong Jockey Club, Sha Tin Racecourse, Hong Kong.ESEA

ABSTRACT:

The aim of this study is to reduce the risk of premature retirement of Thoroughbred racehorses at the Hong Kong Jockey Club. Content analysis of 3727 text records between 1992 and 2004, identified that 13.7% (510/3727) of horses retired due to superficial digital flexor tendon injury.

Materials and Methods

A case control study design was used. A case was a tendon injury retirement, for which the last exercise was at gallop pace. Only 175/510 cases (34.3%) met this case definition. Three controls per case, (525 in total), matched by day of gallop, were randomly selected from uninjured horses. Data were analysed using multivariable conditional logistic regression.

Results and discussion

Ten risk factors were identified e.g. import age, distance raced within 180 days post import, previous veterinary or ultrasound examination and reduced exercise intensity in the 180 days before retirement. Associations with ultrasound examination and reduced exercise frequency, as likely effects rather than causes, provide important indicators for the identification and management of "horses at risk".

An assumption in this study was that a tendon injury, resulting in retirement, would occur at gallop pace. However, the unique clinical records available in HK revealed that two-thirds of cases trotted or cantered, often for many days after their last gallop, before they were retired. This may represent an attempt at rehabilitation or tendon injury during lower intensity exercise. It highlights a major constraint in all observational epidemiological studies of tendon injury – identifying the time of injury. In the present study we attempted to overcome this by including only those horses for which the last exercise was at gallop pace. In further analysis we will remove assumptions about the date of injury by using all 510 cases; and identify incident cases by selecting only those with tendon injury diagnosed by ultrasonographic examination.

Appendix 5

International Conference for Racing Analysts and Veterinarians Proceedings New Zealand 2010 Abstract

Comparison of Descriptive Analysis of Catastrophic Racing Injuries in Japan and Hong Kong

Kenneth Lam[1], Brian Stewart[1], Chris Riggs[2], Kanichi Kusano[3], Sadao Yokota[4], Toshiyuki Takahashi[5] and Tim Parkin[6]

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[5] Equine Research Institute, Japan Racing Association, 321-4, Tokamicho, Utusnomiya-shi, Tochigi, Japan.

[6] Boyd Orr Centre for Population and Ecosystem Health, Institute of Comparative Medicine . Faculty of Veterinary Medicine, University of Glasgow, UK.

Brief Description of Methods:

A retrospective study was conducted using data from computerised records held by the Japan Racing Association (JRA) and Hong Kong Jockey Club (HKJC) official database.

Descriptive analyses were performed with Epiinfo, Version 3.5, Centers for Disease Control and Prevention (CDC), USA, to produce population estimates of parameters (including 95% Confidence Intervals) associated with catastrophic musculoskeletal injuries (CMI) of Thoroughbred racehorses in flat racing at JRA and HKJC over a 7-year period (2002 to 2008 racing seasons).

The pattern of CMI, horse and track characteristics in both racing jurisdictions was compared. Respective profiles on age, career starts, and race distance were analysed by non-parametric Mann-Witney test to assess the statistical significance of differences.

Chi-square tests for trend were used to assess the odds of racing injuries in horses exposed to different racing surfaces.

Purpose and Relevance of the Study

This is the first step towards international harmonisation on the development of management tools to reduce the incidence of CMI in Thoroughbred racehorses by describing and comparing the frequency, career starts and characteristics of the population associated with CMI in JRA and HKJC.

The study aims to benchmark the importance of collaboration through establishment of an international collating centre for racing injury data from different jurisdictions to gain international agreement on appropriate measures of durability in the Thoroughbred racehorses.

Differences in racing management in different racing jurisdictions will then be compared effectively to optimise the longevity and maximise the health and welfare of the Thoroughbred racehorses.

Summary of Results

The average incidence of CMI per 1000 starts in JRA and HKJC were 1.69 (+/- 0.14; 95%CI) and 0.76 (+/- 0.21; 95%CI; $P < 0.001$) respectively. Greater than 85% of total fatalities affected the front legs. The predominant pattern of CMI in JRA was P1 fractures and articular dislocation between P1 and MCIII or MTIII (45%) and in HKJC was proximal sesamoid fractures (45%). There were statistically significant differences in the median age profile and career starts (2 years younger and corresponding 2.8 times fewer career starts in JRA; P<0.001), and gender profile (93% were geldings in HKJC; 66.5% males and 31.3% females in JRA). The chi square test for trend of risk of CMI on Turf and Dirt surfaces in JRA was higher in reference to Turf surface in HKJC (P<0.001).

Conclusion

This descriptive study has provided a useful population based data resource for further collaborative research studies to investigate risk factors, including shoeing practices, track characteristics, pre-race veterinary inspection findings, environmental factors and training/ exercise regimens that are associated with an increased risk of CMI.

Acknowledgement

We wish to thank the support of Department of Veterinary Clinical Services of Hong Kong Jockey Club and Japan Racing Association Clinicians on this preliminary study.

Appendix 6

Guidelines of issue of Official Veterinary Examination (OVE) Criteria

An OVE must be issued in the following cases:

(i)The detection of any significant condition during the conduct of an official post-race or post OVE veterinary examination.

(ii) Bleeders (EIPHS).

(iii)Significant cardiac irregularities.

(iv)Any horse that has been assessed by the Stipendiary Stewards (SS) to have returned an unacceptable performance.

(v) Any horse that has been withdrawn from a race for a veterinary reason.

(vi)Any horse that has undergone a surgical procedure (except uncomplicated castration).

(vii) Any horse that has been diagnosed with a significant (as assessed by a Veterinary Officer (VO)) musculo-skeletal condition with the potential to affect suitability to race in the near future.

It should be noted that the performance of a diagnostic procedure to monitor the condition of a chronic injury or degenerative condition, or which provides evidence of no significant damage to the structure being examined, will not result in the issue of an OVE unless the VO is not satisfied that the cause of abnormality has been identified and/or that a satisfactory prognosis has been provided by the examining VS.

Breathing Obstruction Disorders

(i)The issue of OVE for breathing obstruction conditions has been

problematic.

(ii) Dorsal displacement of soft palate, epiglottic entrapment and

pharyngeal collapse may occur intermittently. Laryngeal hemiplegia may be present, but a horse may still perform to a reasonable standard.

(iii)Nevertheless there is a point at which it is appropriate to issue an OVE

requirement and require the horse to demonstrate its suitability to race.

(iv)Also it is important that the presence of these conditions is disclosed to

the SS, owners and the public.

(v) It is proposed that an OVE requirement for breathing obstruction condition be issued under the following circumstances at all official

veterinary inspection ordered by the Stewards.

(a) Epiglottic Entrapment (EE)

(b) Persistent or frequent intermittent Dorsal Displacement of the Soft Palate (DDSP)

(c) Dynamic Pharyngeal Collapse

(vi)The functional significance of diagnosed airway problems is

recommended to be further investigated by high-speed treadmill video-endoscopic study. This can provide more clinical information on the significance of the condition in affecting performance of the horse and address any welfare concern regarding the horse's suitability to continue racing.

Laryngeal Hemiplegia

The presence of Laryngeal Hemiplegia will be reported when diagnosed and the public advised by the "roarer" database maintained on the Club's website. However, a VO may issue an OVE which will require a High Speed Treadmill evaluation and Barrier Trial at anytime the VO is of the opinion that a horse's suitability to race needs to be investigated and confirmed.

Appendix 7 – Veterinary Regulatory Monitoring System ("To Watch" List) on Clinical Reports (Page 1)

香港賽馬會
The Hong Kong Jockey Club

TO	**All Trainers**	FROM	**Senior Veterinary Officer and Veterinary Officer**		
		VIA	**Head of Veterinary Regulation and International Liaison**		
REF	**VET/M038/05-06**	DATE	**18 April, 2006**	ENCLOSURES	

SUBJECT **Veterinary Regulatory Monitoring System ("To Watch" List) on Clinical Reports**

The Department of Veterinary Regulation and International Liaison (DVR&IL) will, with immediate effect, implement a new system of monitoring horses with injuries or conditions that have potential to affect a horse's future suitability to race.

The objectives of the system are:

1. To improve the monitoring of potential problem horses.
2. To reduce the number of Official Veterinary Examination (OVE) issued for relatively minor problems.

The procedures required for the system are attached in written and flow chart form (**Annex A**).

In essence the system requires that horses reported to have clinical findings of relatively low potential significance are checked by a Veterinary Officer (VO) prior to the horse accepting to race again.

The system differs from the OVE system in the following ways:

1. A clinical examination only is required.
2. The owner is <u>not</u> advised.
3. The condition is <u>not</u> reported on the Club's website.
4. The medication requirements are relaxed compared to the full OVE requirement.
5. The follow-up examination must be performed prior to accepting to race, not prior to entries.

As a guideline, a "To Watch" requirement will be issued for conditions that satisfy the following requirements:

1. Transient problems with a high probability of resolving uneventfully and with low potential significance for affecting a horse's future suitability to race or,

Appendix 7- Page 2

Veterinary Regulatory Monitoring System ("To Watch" List) on Clinical Reports
18 April 2006

2. Reoccurrences of chronic conditions that are unlikely to have welfare, performance or safety implications and that are likely to return to the baseline condition uneventfully

The system will be administered by the Clinical Follow-up Veterinary Examination Notification Form attached at **Annex B**.

Although, the Veterinary Surgeon (VS) is not required to complete the Clinical Follow-up Veterinary Examination Notification Form, please be advised that the VO is unlikely to be satisfied with the condition of the horse, unless it has been re-examined by the Stable VS and a clinical record of the management of the condition is entered in the Veterinary Clinical Services Department's VMIS.

In other words, please ensure that your Stable VS performs a follow-up examination of the horse and is satisfied with its condition prior to requesting an official veterinary inspection.

To ensure that horses are not presented to a Pre-race Veterinary Inspection without assessment, a list of horses with outstanding follow-up examination requirements that have entered to race will be issued on the day of entries, so that the Stable VS can follow-up any outstanding cases and an official inspection can be arranged prior to acceptances.

Please be aware that all horses that show significant clinical findings during any official veterinary inspection ordered by the Stewards will be issued with an OVE.

If you have any questions, please contact an officer of the DVR&IL.

B D Stewart BVSc (Hons) MBA

K H Lam, BSc (Hons), BVetMed, Cert VA, MRCVS

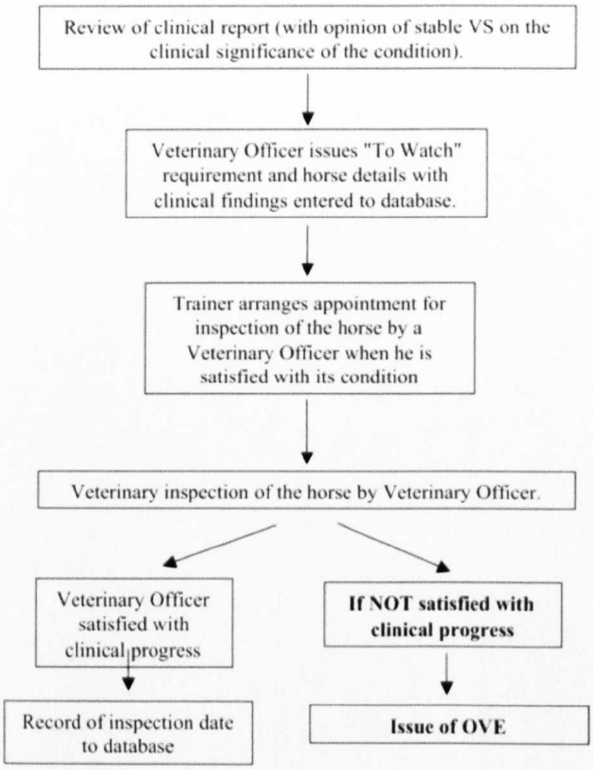
/cc

cc CSS
HVCS
VS

Appendix 7- Page 3

Annex A

To-watch list Follow-up flowchart



香港賽馬會
The Hong Kong Jockey Club

Annex B

Clinical Follow-up Veterinary Examination Notification Form
(To Watch List)

To: Trainer: ____________________

Horse Name: ____________________ **Horse No.:** ____________________

(A) Department of Veterinary Regulation and International Liaison

Upon receipt of the diagnostic clinical report issued on ____________ (date), please be advised that the above horse is subject to a follow-up clinical examination by a Stable Veterinary Surgeon, and to be followed by a veterinary inspection by a Veterinary Officer prior to acceptance of the horse to race again.

Reason: ____________________

____

____________________ ____________________
*** Senior Veterinary Officer / Veterinary Officer** **Date**

(B) Trainer

I am satisfied that the horse has recovered from the above condition and wish to arrange an inspection of the horse on ____________ (date).

[Please ensure that your Stable Veterinary Surgeon is satisfied with the condition of the horse prior to arranging the inspection by a Veterinary Officer.]

The last date of administration of analgesic / anti-inflammatory treatment: ____________

[Please consult with your Stable Veterinary Surgeon.]

____________________ ____________________
Trainer **Date**

(C) Department of Veterinary Regulation and International Liaison

(I) Results of veterinary inspection by Veterinary Officer: * Acceptable / Not Acceptable

Comments: ____________________

____

(II) Issue of OVE Required: * Yes / No **Date of Issue:** ____________

Reason: ____________________

____

____________________ ____________________
*** Senior Veterinary Officer / Veterinary Officer** **Date**

*** Delete as appropriate**

cc: HVR&IL / HVCS / Stable VS

DVR&IL Form / April 2006