Epidemiological investigations of equine welfare at OSAF jurisdiction racecourses

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Abstract

Horseracing activity (flat racing and breeding) in Latin America is nowadays a very important industry and concern regarding the welfare of the Thoroughbred continues to grow.

Even though many epidemiological investigations have been conducted in Thoroughbred flat racing throughout the years, to the best of the author's knowledge, no previous study has been published that identifies risk factors for fatalities and musculoskeletal injuries (MSI) in horse racing in Latin America.

There are several clear differences between racing industries around the world, suggesting that risk factors for unwanted outcomes in Thoroughbred racing are likely to differ. It is therefore important to use local data and knowledge to develop region or even track specific models to identify the risk factors and militate against fatal and non-fatal injury.

This study was focused on describing the prevalence of fatalities and MSI at four different racecourses under OSAF (Latin American Organization for the Promotion of the Thoroughbred) jurisdiction and identifying risk factors amongst them. The analysis involved approximately 500,000 race starts provided by OSAF racecourses. Multivariable logistic regression models were developed for each racetrack independently in order to identify multiple risk factors for both outcomes. A further combined analysis was also conducted combining two racecourses that belong to the same country to improve statistical power.

Many risk factors were identified as being associated with one or both outcomes, such as: older, male and heavier horses were all associated with an increased risk as were horses for whom the trainer had declared the use of phenylbutazone. We believe that this is the first study to clearly demonstrate the relationship between medication regulations and equine welfare.

The results of this study could help develop strategies aimed at reducing and preventing equine musculoskeletal injuries and fatalities and may encourage new medication policies that seek to optimize welfare for Thoroughbred racing in flat races within the OSAF jurisdiction.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signature ____

Printed name _____Teresita Zambruno___________________________________

Definitions/Abbreviations

OSAF=Latin American Organization for the Promotion of the Thoroughbred

IFHA=International Federation of Horseracing Authorities

MSI=Musculoskeletal injury

Y=yes

AUS=Australia

JAP=Japan

NZ=New Zealand

UK=United Kingdom

USA=United States of America

CNS=Central Nervous System

BHA=British Horseracing Authority

EID=Equine Injury Database

AIC=Akaike Information Criterion

OR=Odds Ratio

CI=Confidence Interval

FB=Phenylbutazone

FS=Furosemide

FF=Phenylbutazone and Furosemide

Kg=Kilograms

K/h=Kilometres per hour

1 Review of the Literature

1.1 Introduction

1.1.1 Horseracing Background

The Thoroughbred is the most valuable breed of horse in the world and has been prized as a racehorse for centuries. The enthusiasm of the British aristocracy for racing in the 17th century led to the development of the Thoroughbred (Bower, et al., 2012). Nowadays horseracing is watched in almost every nation of the world. The industry associated with this sport is responsible for the employment of an enormous number of people, as well as for the breeding and care of a significant number of horses. Only during the year 2014, 86,465 Thoroughbred horses were born in 48 countries worldwide. A significant amount of money is associated with horseracing; in 2014 almost €3 billion were awarded as prize money worldwide (jump and flat races), and gambling associated with horse racing was estimated to be worth over €95 billion. Based on reports from international racing authorities; worldwide in 2014 there were 146,646 officially regulated flat races (involving 1,344,761 starts and 225,526 different thoroughbred horses) and 8,413 jump races (involving 78,720 starts and 21,119 different thoroughbred horses).[1]

1.1.2 Horseracing in Latin America

In Latin America, towards the end of 17th century and beginning of 18th century, a type of horserace called "cuadreras" started. These were run over short distances, generally straight and generated great enthusiasm amongst people. This initial stage of horse racing in Latin America was quickly influenced in its style by new arrivals from Europe, and English immigrants who brought along their passion for horseracing and references from England. Finally in the year 1826, the first "English style races" were held. They were mostly run by creole horses and a few half blood, products of the breeding with thoroughbred horses left after the English invasions in 1806. In 1857 the first official Racecourse at Buenos Aires was inaugurated.[2]

[1] IFHA Official website
[2] "Hablemos de Turf" website.

During the last century, the growing equestrian industry in Latin America resulted in the need to form a stronger bond between organisations related to horse racing activity within the region and it relations at an international level. In the year 1958 OSAF (Latin American Organization for the Promotion of the Thoroughbred) was created, integrating the most important Jockey Clubs, Racecourses, Equestrian Institutions, Stud Books, Breeders and Owners Associations of Latin America and counting amongst its country members Argentina, Brazil, Colombia, Chile, Ecuador, Mexico, Panama, Paraguay, Peru, Uruguay and Venezuela.[3]

Horseracing activity (flat racing and breeding) in Latin America is nowadays a very important industry. During 2014, there were 211,697 starts in 21,587 officially regulated races (involving 37,515 different horses) in seven OSAF countries (Argentina, Brazil, Chile, Mexico, Peru, Uruguay and Venezuela). In that same year, 15,672 Thoroughbred horses where born in those seven countries. Argentina stood as the third largest producer worldwide of Thoroughbred horses with 8,028 births.[4]

1.1.3 Injuries

Injuries (fatal and non-fatal) in horses during racing are very significant for the industry; they not only affect racehorse welfare but jockey safety and the public perception of horseracing too. Unfortunately, horses involved in racing are at risk of sustaining an injury. Developing strategies for reducing and preventing equine injuries is essential for racing activity and horse welfare. In order to do this we must identify the risk factors associated with different injury types.

Previous researchers have identified risk factors for injuries in different regions of the world. Risk factors for different outcomes have been identified by studies conducted in UK (Parkin, et al., 2004a; Parkin, et al. 2004b; Lyle, et al., 2012; Reardon, et al., 2012), Australia (Bailey, et al., 1997; Cogger, et al., 2006; Boden, et al., 2006; Boden, et al., 2007), New Zealand (Perkins, et al., 2005a), Japan (Takahashi, et al., 2004) and USA (Mohammed, et al., 1991; Estberg, et al., 1995; Estberg, et al., 1996a; Estberg, et al., 1998b; Kane, et al., 1996; Kane, et al., 1998; Cohen, et al., 2000; Hernandez, et al., 2001).

[3] OSAF Official website
[4] IFHA Official website

Even though many risks factors have been identified throughout the years, as far as we know no study has ever been conducted to identify risk factors in Latin America's horseracing. Risk factors may differ among countries, and even regions within countries, and research into risk factors should be focused at a regional level (Boden, et al., 2007).

There are clear differences in the Latin American racing industry, compared to other regions, which means that not all of the already identified risk factors may be applicable. For example, there are some races in Latin America in which horses may run while using furosemide and/or phenylbutazone. Having this in mind, this could result in the identification of new risk factors for this region that, if modifiable, are more likely to reduce the risk of racehorse injury in South America.

This study is focused on describing the prevalence of fatalities and musculoskeletal injuries in racehorses on racecourses under OSAF jurisdiction. A multivariable analysis will be conducted in order to identify risk factors (for different outcomes) at OSAF racecourses separately. Where key welfare issues are similar and there is reason to analyse data together this will be done to increase statistical power.

1.1.4 Identifying risk factors

To identify risk factors it is required to identify a type of injury (outcome) and a population of horses to study. The identification of risks through the years has been facilitated by improvement of data recording like the introduction of injury recording schemes and use of computerised databases. Even though the number and size of studies have increased, the information reported is subject to certain limitations. In a lot of studies information is only collected by official veterinarians at the racecourse, which means that injuries that are not diagnosed at that moment on that can occur during training are not included.

Identification of risk factors commonly relies on the identification of statistically significant associations between these risk factors and an outcome. Significant associations are those that occur more frequently than what would be expected by chance, meaning how much more likely an outcome is to occur taking into account a specific variable of study.

Potential risk factors can be grouped based on their origin into those associated with: the horse; the racecourse; the trainer; the jockey; and the individual race. Within these categories there is considerable interconnection (Ross and Dyson, 2011).

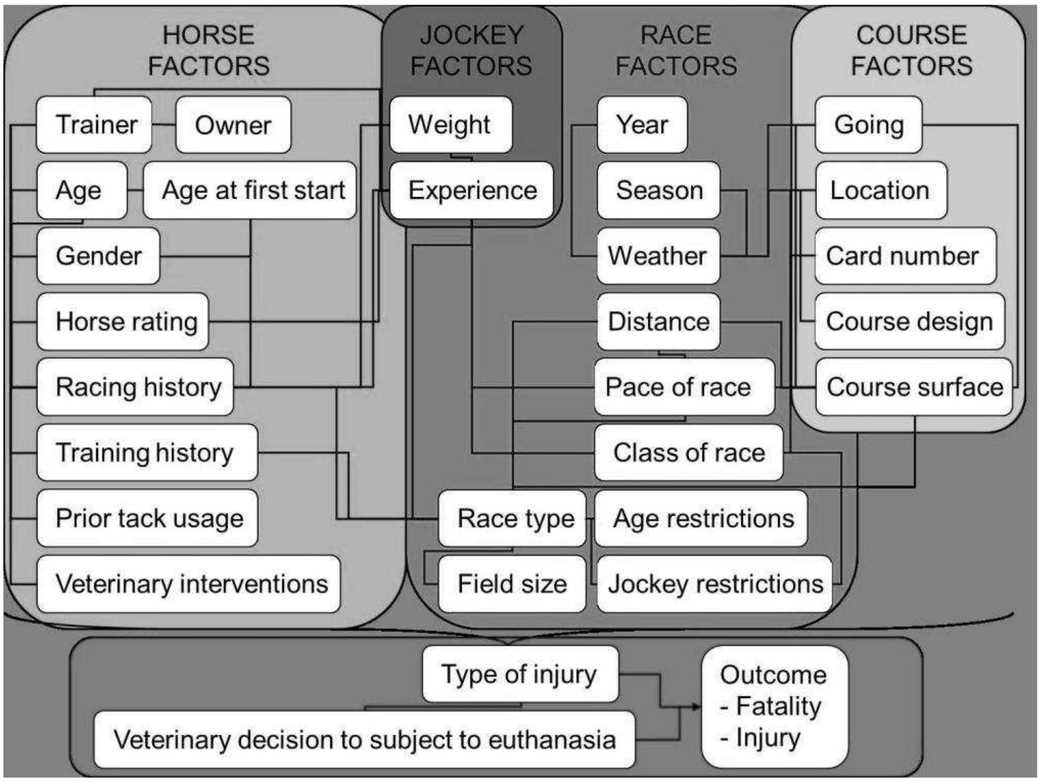

Figure 1-1: Risk factors and interactions between them. (Ross and Dyson, 2011)

1.2 Musculoskeletal injury

Musculoskeletal injury (MSI) is a common definition used in many risk factor studies, although the exact injury outcome definition of MSI varies. Some studies include only MSI which resulted in fatality, (included in Table 1-1), while others included a definition of severe MSI, which resulted in either death or a period away from racing (included in Table 1-2). There are some studies which are about a specific MSI such as specific fractures (included in Table 1-3) or tendon and ligament injuries (included in Table 1-3).

Studies in which MSI include a group of severe injuries are less specific than those in which MSI is defined at the level of the specific anatomical structure. Nevertheless, they provide very valuable information about a general outcome of interest for racehorses and add statistical power to the study since the number of cases is increased.

MSI in this study include severe injuries that may end in the horses' death or a period away from racing; these include fatal and non-fatal fractures, exposed luxations and tendon and ligament injuries. Having this in mind the literature review will include reference to work on a broad range of MSIs, including groups of severe injuries and also specific outcomes such as fractures and tendon and ligament injuries in Thoroughbred horse racing.

Table 1-1: Studies which include only MSI which resulted in fatality

Fatal MSI			
Country	USA		
Region	California	USA and Canada	Florida
References	*(Estberg et al. 1996a)* *(Estberg et al. 1998a)* *(Estberg et al. 1998b)* *(Estberg et al., 1995)* *(Kane et al., 1998)* *(Kane et al., 1996)*	*(Georgopoulos & Parkin 2016a)*	*(Hernandez et al. 2001)*

Studies present on Table 1-1 are those in which MSI include the cases in which the severity of the injury ended in the death of the horse. In this particular case, all of them belong to studies conducted in the USA, California and Florida in those in which the region is specified and all USA plus Canada as well in the case of (Georgopoulos & Parkin, 2016a). Some of them are studies to determine risk factors for the studied outcome while some others are an investigation of the relationship between the outcome and a particular variable or characteristic.

Table 1-2: Studies which include MSI which resulted fatality or a period away from racing

Fatal and non-fatal MSI			
Country	Australia	UK	USA
Region			Kentucky
References	*(Bailey et al., 1997)* *(Cogger et al., 2006)*	*(Verheyen et al., 2010)* *(Cohen et al., 1997)* *(Ely et al., 2009)*	*(Cohen et al., 2000)* *(Peloso et al., 1994)*

Studies referenced in Table 1-2 include different countries and specific regions, such as Kentucky in USA. All of them include MSI that resulted in the horse death or in a period away from racing. Cases included in these studies are probably more variable than those included in Table 1-1. Some of them are serious fractures while other are much less severe injuries such as in the case of Verheyen et al. (2010), which describes factors associated with dorsometacarpal disease. Some of them not only search for associations between factors but describe prevalence as well (Peloso et al. 1994). Some of these studies are risk factors investigations while others are simply descriptive epidemiology (Ely et al. 2009).

Table 1-3: Studies which include MSI that were fractures

Fractures/Specific Fractures			
Country	UK	USA	
Region		California	USA/Canada
References	*(Parkin et al., 2004b)* *(Verheyen et al., 2006)* *(Parkin et al. 2006a)* *(Parkin et al., 2005)*	*(Carrier et al., 1998)*	*(Georgopoulos & Parkin 2016b)*

Studies included in this table are those in which the studied outcome was a fracture and in some cases a specific fracture, of a particular bone, or region of a determined bone. The variability of the cases reduces considerably in this kind of outcome ensuring that risk factor associations are likely to be more robust and specific to the outcome of interest. Studies of this magnitude have been made in different regions of the USA and in the UK involving not only flat races but also hurdle and steeplechase races.

Table 1-4: Studies which include MSI that were tendon and ligament injuries

Tendon and Ligament Injuries				
Country	New Zealand	UK	Hong Kong	Japan
Region				
References	*(Perkins et al. 2005a)*	*(Reardon et al., 2012)*	*(Lam et al., 2007)*	*(Takahashi et al., 2004)*

New countries appear in these studies which involve a very specific outcome, namely MSI that include tendon and ligament injuries. Although these are, in the majority of the cases, a type of injury that are not immediately life-threatening, they are also very common among Thoroughbred racehorses around the world, and they are an important common reason for retirement.

1.2.1 Risk factors for MSI

Many risk factors associated with MSI have been determined throughout the years in different regions worldwide. It is worth mentioning that there are a larger number of studies that determine risk factors, and Table 1-5 is an example and a representation of the most frequent published risk factors for MSI in horse racing. Table 1-5 shows some of the variables reported as being significantly associated with increased odds of MSI in thoroughbred racing. The country where the study was conducted and references for each studied variable are specified in Table 1-5.

Table 1-5: Variables reported as being significantly associated with increased likelihood of MSI in horseracing. "Y" (yes) boxes correspond to variables with significant association with the studied outcome.

COUNTRY	REFERENCE	AGE	GENDER	DISTANCE	HORSE WEIGHT	RACE TYPE	TRAINNING HISTORY	RACING HISTORY	FIELD SIZE	TRACK/ SURFACE	GOING	SEASON	PREVIOUS INJURIES	JOCKEY EXPERIENCE
		RISK FACTOR FOR MSI												
AUS	*(Bailey et al., 1997)*	Y				Y								
	(Boden et al., 2007)		Y	Y				Y						
JAP	*(Takahashi et al., 2004)*		Y	Y	Y									
NZ	*(Perkins et al. 2005a)*	Y	Y					Y					Y	
UK	*(Verheyen et al., 2010)*						Y							
	(Parkin et al., 2004b)			Y				Y	Y		Y			
	(Parkin et al. 2006b)						Y	Y						
	(Reardon et al., 2012)	Y									Y	Y	Y	
	(Parkin et al., 2005)						Y	Y	Y		Y			Y
	(Henley et al., 2006)	Y		Y		Y		Y			Y			
USA	*(Mohammed et al., 1991)*	Y						Y		Y				
	(Estberg et al., 1995)						Y	Y						
	(Estberg et al. 1998b)	Y	Y			Y								
	(Estberg et al. 1996b)	Y	Y											
	(Hernandez et al., 2001)		Y					Y		Y				
	(Georgopoulos & Parkin 2016a)	Y	Y	Y		Y	Y	Y		Y			Y	
	(Georgopoulos & Parkin 2016b)	Y	Y	Y		Y	Y	Y		Y			Y	

Country abbreviations: AUS (Australia), JAP (Japan), NZ (New Zealand), UK (United Kingdom), USA (United States of America).

Increased horse age was significantly associated with increased likelihood of MSI in all studies, although in some of them this association was not linear, and in the case of Estberg et al. (1998b) the influence of age on risk depended on the race type. Male horses were associated with an increased odds of injury compared with female in all mentioned studies. As regards race distance, most investigations show than longer racing distances represent a higher risk when we consider MSI as the outcome, due to longer exposure to the risk and fatigue of musculoskeletal structures. Georgopoulos & Parkin (2016) on the other hand have demonstrated a lower risk for fracture and fatal injury as distance increases in the USA. They suggest that this difference is due to the difference in the range of race distances over which races are conducted in North America. Races tend to be shorter in North America than most of the rest of the world, so there is greater emphasis on speed throughout the whole of the race. It is this potential association with speed in short races that the authors believe to be the reason for the reversed finding with respect to race distance in North America compared with elsewhere. Heavier horses were found to be at higher risk when considering tendon and ligament injuries as an outcome in Japan (Takahashi, et al., 2004).

As regards to race type, study results are more variable since in some areas more competitive type of races (higher quality races) were riskier (Bailey, et al., 1997), while in others the risk was higher in lower quality races (Estberg, et al., 1998b). Comparing steeplechase and hurdle races with flat races, the later represented a lower risk (Henley, et al., 2006).

There are many investigations that take into account racing or training history of the horses. Accumulation of racing distance, type and period of training, frequency of racing, etc. are variables that could lead to accumulation of significant exercise-induced microdamage or inappropriate bone adaptation in thoroughbred horses. This is valuable information when considering risk factors for MSI and results about these types of variables are extensive.

Considering field size as a risk factor, races with larger number of runners were found to be significantly associated with a higher risk of injury, since there are more runners exposed to injury risk and that there could be more physical interaction between competitors leading to an accident. It is also the case that more competitive or more high-profile races tend to have more runners so that horses racing in such races are perhaps encouraged more or indeed compete more intensively than they would otherwise do so in less ‘important’ races.

As regards type of track or racing surface, studies show different risk results. Some of them indicate that running on turf is riskier than running on dirt while others show the opposite. Although track conformations may differ resulting in softer or firmer surfaces, different confounding factors should be taken into consideration to explain these differences.

Going of the surface is perhaps a clearer risk factor than racing surface, since studies have demonstrated that firmer going or firmer surface is always riskier for MSI, both fracture and tendinopathy.

There are not many studies that include the season of the year as a variable, but summer season has been demonstrated to be riskier than other seasons for tendinopathy.

Previous recorded injuries have obviously been demonstrated to be a big risk for serious MSI for tendinopathy in the UK, New Zealand and North America.

Finally, jockey experience was also investigated, resulting in a bigger risk when horses were being ridden by less experienced jockeys.

1.3 Fatalities

Fatalities taken into account in published studies belong to those deaths occurred exclusively at the racecourse (or in some cases those that occur within the next 24 hours), but there are in fact many more racing related fatalities (after leaving the racetrack or in training) that are not taken into account for these kind of studies.

The definition of fatality as an outcome is easier than MSI, since in the former the result is always the death of the horse. The causes of death varies within the different studies. Some of them include only sudden death cases, others include MSI that ended in a fatality or euthanasia (and some others include sudden death, fatal MSI and central nervous system (CNS) trauma. Details of this differentiation are showed in Table 1-6. Studies in which the cause of the fatality is a fatal MSI are more common within the MSI section.

Table 1-6: Causes of fatality between different studies

Outcome cause	**Fatal MSI**		**Sudden death**	**Fatal MSI, Sudden death and CNS Trauma**
Country	USA	UK	UK	Australia
References	*Estberg et al. 1995, 1996b, 1998b Georgopoulos & Parkin 2016a Hernandez et al. 2001 Kane et al. 1996, 1998*	*Henley et al. 2006 Parkin et al. 2004a, 2004b, 2004c, 2005,2006b*	*Lyle et al. 2012*	*Boden et al. 2007, 2010*

Fatalities in horse racing are usually reported and published as number per thousand starts. These rates vary significantly worldwide and between race types as well; for example in the UK fatalities per thousand starts are remarkably higher in Hurdle, Steeplechase and National Hunt Flat (NHF) than in flat races (Reardon, et al., 2013) (included in Table 1-7). Recorded details of all injuries and fatalities in UK are collected under a computerised database called “The Equine Welfare Database”, established by the British Horseracing Authority (BHA - the governing body for horseracing in Great Britain) in the year 2000. Later, in the year 2008, the USA Jockey Club initiated the EID (Equine Injury Database), which collects racehorse injury data from USA and Canada and helps calculate rates by year for that part of the world. USA fatality rates are sown in Table 1-8[5]. Rate differences between regions could be the result of the differences of the study population sizes and racing industries between countries such as racing regulations, authorized medications, climate, type of breeding, training, etc. or even cultural differences. Rate differences over time within the same region (EID), could be the result of changes implementations for minimising risks or improvement in treatment of horses seeking survival.

Table 1-7: Fatality rates in UK from 2000 to 2009. (Reardon et al. 2013)

	Hurdle	Steeple	NHF	Flat	TOTAL
Starts	185826	113327	27848	570249	897250
Fatalities	860	705	76	445	2086
per 1000 starts	**4.6**	**6.2**	**2.7**	**0.8**	**2.3**

Table 1-8: Fatality rates in USA by year 2009-2015. (EID,The Jockey Club website)

Statistical Summary. Thoroughbred only							
Calendar Year	2009	2010	2011	2012	2013	2014	2015
Fatalities/1000 starts	**2**	**1.88**	**1.88**	**1.92**	**1.9**	**1.89**	**1.62**

1.3.1 Risk factors for Fatality

Many risk factors associated with fatality have been determined throughout the years in different regions worldwide. Table 1-9 shows some of the variables reported as being significantly associated with increased odds of fatality in thoroughbred racing. Country where the study was conducted and references for each studied variable are specified in the table. Many of these risk factors have indeed been determined for MSI when an MSI was considered to be a fatal event.

[5] The Jockey Club. Available at www.jockeyclub.com

Having this in mind, many references are used both for MSI and for fatality risk factors.

Table 1-9: Variables reported as being significantly associated with increased likelihood of Fatality in horseracing. "Y" (yes) boxes correspond to variables with significant association with the studied outcome.

COUNTRY	REFERENCE	RISK FACTOR FOR FATALITY										
		AGE	GENDER	DISTANCE	RACE TYPE	TRAINNING HISTORY	RACING HISTORY	FIELD SIZE	TRACK/ SURFACE	GOING	PREVIOUS INJURIES	JOCKEY EXPERIENCE
AUS	*(Boden et al., 2007)**		Y	Y			Y					
UK	*(Parkin et al., 2004b)**			Y			Y	Y		Y		
	*(Parkin et al. 2006b)**					Y	Y					
	*(Parkin et al., 2005)**					Y	Y	Y		Y		Y
	*(Henley et al., 2006)**	Y		Y	Y		Y			Y		
	(Lyle et al., 2012)	Y		Y	Y		Y					
USA	*(Estberg et al., 1995)**					Y	Y					
	*(Estberg et al. 1998b)**	Y	Y		Y							
	*(Estberg et al. 1996b)**	Y	Y									
	*(Stamatis P Georgopoulos and Parkin, 2016a)**	Y	Y	Y	Y	Y	Y		Y		Y	
	*(Hernandez et al., 2001)**		Y				Y		Y			

*Studies also referenced in Table 1-5.

In Table 1-9 it can be noticed that almost all references, with the exception of Lyle et al., (2012), are relevant for fatality and MSI risk factors since they refer to fatal MSI. The former reference identifies risk factors for sudden death only, which are not uniquely associated with sudden death and have also been identified in studies using all causes of fatality as the outcome.

The comparison of Table 1-5 and 1-9 shows that only horse weight and season of the year have been identified as an exclusive risk factor for MSI but not for fatality. Both tables are in fact very similar since most of the causes of fatality in those studies are musculoskeletal in nature.

1.4 Aim of risk factors studies

The most important aim of risk factors studies for fatality or fatal and non-fatal MSI is using its results in order to create strategies to prevent and reduce the risk of the studied outcome. Studies have demonstrated that it is crucial to run as many analyses as possible, be specific about the outcome and the studied population to see if new or unique risk factors can be identified. Studies have also demonstrated that there are many risk factors that are common between different regions while some others are exclusive to specific sectors or types of discipline, which encourages the industry to keep researching worldwide.

2 Musculoskeletal Injuries

2.1 Introduction

2.1.1 MSI in racing

Musculoskeletal injuries (MSI) in racehorses are very common, they may disrupt training and racing, often demanding long periods of rest or, in severe cases, retirement or euthanasia (Perkins, et al., 2005b). Public perception of the sport is adversely affected by the occurrence of MSI on the racecourse. Moreover, they seriously affect jockey's safety and severely impact on equine welfare.

Racehorses fatality and injury rates have been reported to vary significantly between racecourses (Mohammed, et al., 1991; Parkin, et al., 2004b; Williams et al., 2001). This suggests that characteristics of certain regions or tracks, the demographics of different racehorse populations, or variations in training methods are associated with increased or decreased risk of MSI.

2.1.2 Risk factors for MSI

Even though many risk factors for MSI have been identified in Thoroughbred flat racing throughout the years, to the best of the author's knowledge, no previous study has been published that identifies risk factors for MSI in horse racing in Latin America.

Risk factors for different outcomes which include MSIs had been identified throughout different regions. In the UK, risk factors for fatal distal limb fracture (Parkin, et al., 2004b; Parkin, et al., 2005; Parkin, et al., 2006b), dorsometacarpal disease (Verheyen, et al., 2010), fatalities (Henley, et al., 2006) and tendinopathy (Reardon, et al., 2012) have been identified. In Australia, work has identified risk factors for fatality (Boden, et al., 2007) and MSI (Bailey, et al., 1997; Cogger, et al., 2006). In New Zealand (Perkins, et al., 2005b) and Japan (Takahashi, et al., 2004) risk factors for superficial digital flexor tendon injuries have also been investigated. In USA, risks factors for breakdown (Mohammed, et al., 1991), fatal MSI (Estberg, et al., 1995; Estberg, et al., 1996a; Estberg, et al., 1996b; Estberg, et al., 1998a; Estberg, et al., 1998b; Hernandez, et al., 2001) and MSI (Cohen, et al., 1997) have been investigated in numerous regional (state or racing jurisdiction) analyses.

There are several clear differences between racing industries around the world, suggesting that risk factors for unwanted outcomes in Thoroughbred racing are likely to differ. It is therefore important to use the local data and knowledge to develop region or even track specific models to identify the risk factors for and militate against fatal and non-fatal MSI.

This study is focused on describing the prevalence of MSI at three different racecourses under OSAF jurisdiction and identifying risk factors for MSI amongst them.

2.2 Materials and methods.

2.2.1 Available data

Cases of MSI in this study included injuries which may result in the horse death, retirement from racing or a period of at least six months away from racing. All MSIs were confirmed as such by racecourse veterinarians working at the racetracks from which data were received. Horses that required assistance for removal from the racetrack were eligible for inclusion in the study. All cases of MSI were horses displaying obvious lameness and had sustained a fracture, tendon or ligament injury or joint luxation.

Data shown in this chapter belong to three different OSAF racecourses from two different countries. They will be called racecourses “A”, “B” and “C”. Racecourses B and C are from the same Latin American country.

Race start data was recorded as a computerised database at each racecourse, and MSI reports were provided on paper by official veterinarians from each of the racetracks.

It was necessary to check the accuracy of veterinarian’s reports by confirming their criteria and validating information contained in the reports against information contained in the database. All horses identified as scratched (i.e. removed from a race in which they were originally due to compete) in the race start data were removed from the start file.

2.2.2 Descriptive analysis

The overall risk of MSI and the risk by year and track were calculated using the method described by Wilson, (1927) to calculate 95% confidence intervals around point estimates. All measures of risk were calculated as the number of events per 1000 starts. Simple chi squared tests were used to identify statistically significant differences in the risk of MSI in different years or on different racetracks.

2.2.3 Risk Factor Analysis

Analysis is based on data provided by three of the 14 official racecourses from OSAF jurisdiction. The data includes information on racing MSI and starts of Thoroughbred horses running on racetracks “A”, “B” and “C” during 11, 10 and six-year periods, respectively. A further analysis was also conducted which combined the data from racecourse “B” and “C”, in order to improve statistical power, since they belong to the same country and many horses would race at both tracks in the same season.

The studies were conducted with the outcome of interest (MSI) being measured at the level of a start (a “start” being a horse starting a race).

The retrospective study involved 160 case starts (that resulted in MSI) and 112,028 control starts for racecourse “A”, 359 case starts and 180,965 control starts for racecourse “B” and 202 case starts and 101,667 control starts for racecourse “C”.

2.2.3.1 Selection of cases and controls

A case start was defined as a start in a race, subsequent to which the horse suffered a fatal or non-fatal MSI. Control starts were defined as any start in a race, which did not end in a fatal or non-fatal MSI. Starts made by horses that sustained non-MSI, fatal or non-fatal injuries during a race were excluded from the population of starts from which controls were selected.

2.2.3.2 Risk factors

A total of 18 variables were available for analysis from data collected relating to Racecourse “A” (seven categorical and 11 continuous), 27 for Racecourse “B” (11 categorical and 16 continuous), 25 for Racecourse “C” (11 categorical and 14 continuous). For the analysis of Racecourses "A + B" a total of 23 variables were available for analysis (eight categorical and 15 continuous).

2.2.3.3 Power of the study

All models had at least 80% power to identify odds ratio of 1.5 or more, with 95% confidence, when the prevalence of exposure in the control population was between 10% and 80%.

2.2.3.4 Statistical Methods

All available variables were analysed and screened independently for each racecourse. Continuous variables were categorized into quintiles in order to examine the shape of their potential relationship with the outcome variable. Akaike Information Criterion (AIC) was calculated for continuous variables and their categorized version in order to assess which form best improved the final model. Those that had a lower AIC were taken forward for the multivariable model along with every categorical variable. Unless otherwise indicated by a significantly improved AIC for categorical versions of continuous variables, a linear relationship between each continuous variable and the likelihood of MSI was assumed. Details of these variables and results for each Racecourse are shown in section 2.3.4.1 Risk factor analysis, Univariable results.

Multivariable logistic regression models were developed for each (combination of) track(s) in order to identify multiple risk factors for MSI. All variables were included in an automated stepwise logistic regression selection process to adjust for potential confounding resulting in the development of four final multivariable logistic regression models. Different models were produced for Racecourses "A", "B", "C" and "B + C".

The potential effect of horse in the data analyses was evaluated by creating a mixed-effects model that included horse as a random effect (Reardon, 2013; Boden, et al., 2007; Lyle, et al., 2012). Results were nearly identical (less than 10% change in ORs and no meaningful changes in P values) to results obtained with models that did not include random effects so the single level fixed models were retained.

2.3 Results

2.3.1 MSI per year

The number and risk of MSI varied between years. The frequency of MSI per 1000 starts and number of MSI that occurred at OSAF's racecourses for each year are shown in Table 2-1. The risk of MSI ranged from 1.33/1000 starts (2010) to 2.16/1000 starts (2015) with an overall mean risk over the full 11-year period of 1.82/1000 starts (95% Confidence Interval (95% CI): 1.70-1.96).

Table 2-1: Frequency of MSI per 1000 starts and number of MSI per year at participating OSAF racecourses, with 95% confidence intervals (95% CI) for frequency estimates and number of racecourses contributing data to each year from 2005 to 2015.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
Starts	9390	25152	25406	26534	26929	45085	48370	45754	47727	47361	47673	395381
Number of Racecourses	1	2	2	2	2	3	3	3	3	3	3	3
MSI	19	47	37	55	50	60	80	83	99	88	103	721
per 1000 starts	**2.02**	**1.87**	**1.46**	**2.07**	**1.86**	**1.33**	**1.65**	**1.81**	**2.07**	**1.86**	**2.16**	**1.82**
95% CI	1.39-3.16	1.41-2.48	1.06-2.01	1.59-2.70	1.41-2-45	1.03-1.71	1.33-2.06	1.46-2.25	1.70-2.52	1.51-2.29	1.78-2.62	1.70-1.96

2.3.2 MSI per racecourse

The number of MSI varied between year and racecourse, for example the overall incidence of MSI on Racecourses B and C (from the same country) were very similar, while the risk at Racecourse A was lower. The risk of MSI per 1000 starts and number of MSI that occurred at each racecourse for each year are shown in Table 2-2, and represented graphically in Figure 2-1. In most years, where data were available for all three racetracks, the risk of MSI was lower at Racecourse A than either Racecourse B or C. There were some years in which the risk of MSI was statistically significantly lower on Racecourse A compared with Racecourse B or C. For example, in 2013 the risk of MSI on Racecourse A was significantly lower than that on Racecourse B (p-value = 0.008) and Racecourse C ($P<0.001$). Overall, using all available data, the risk of MSI on Racecourse A (between 2005 and 2015) was significantly lower than that on Racecourse B (2006 to 2015) (p-value = 0.001) and Racecourse C (2010 to 2015) (p-value = 0.002).

Table 2-2: Frequency of MSI per 1000 starts and number of MSIs each year, subdivided between the different racecourses, with 95% CI.

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
A	Starts	9390	9660	9861	9511	9545	9963	11076	10690	11370	10569	10553	112188
	MSI	19	22	18	15	9	10	12	13	9	12	21	160
	per 1000 starts	**2.02**	**2.28**	**1.83**	**1.58**	**0.94**	**1.00**	**1.08**	**1.22**	**0.79**	**1.14**	**1.99**	**1.43**
	95% CI	1.30-3.16	1.50-3.45	1.15-2.88	0.96-2.60	0.50-1.79	0.55-185	0.62-1.89	0.71-2.08	0.42-1.50	0.65-1.98	1.30-3.04	1.22-1.66
B	Starts		15492	15545	17023	17384	18340	19967	19009	18604	18843	21117	181324
	MSI		25	19	40	41	21	41	36	38	42	56	359
	per 1000 starts		**1.61**	**1.22**	**2.35**	**2.36**	**1.15**	**2.05**	**1.89**	**2.04**	**2.23**	**2.65**	**1.98**
	95% CI		1.09-2.38	0.78-1.91	1.73-3.20	1.74-3.20	0.75-1.75	1.51-2.78	1.37-2.62	1.49-2.80	1.65-3.01	2.04-3.44	1.79-2.20
C	Starts						16782	17327	16055	17753	17949	16003	101869
	MSI						29	27	34	52	34	26	202
	per 1000 starts						**1.73**	**1.56**	**2.12**	**2.93**	**1.89**	**1.62**	**1.98**
	95% CI						1.02-2.48	1.07-2.27	1.52-2.96	2.23-3.84	1.36-2.65	1.11-2.38	1.73-2.28

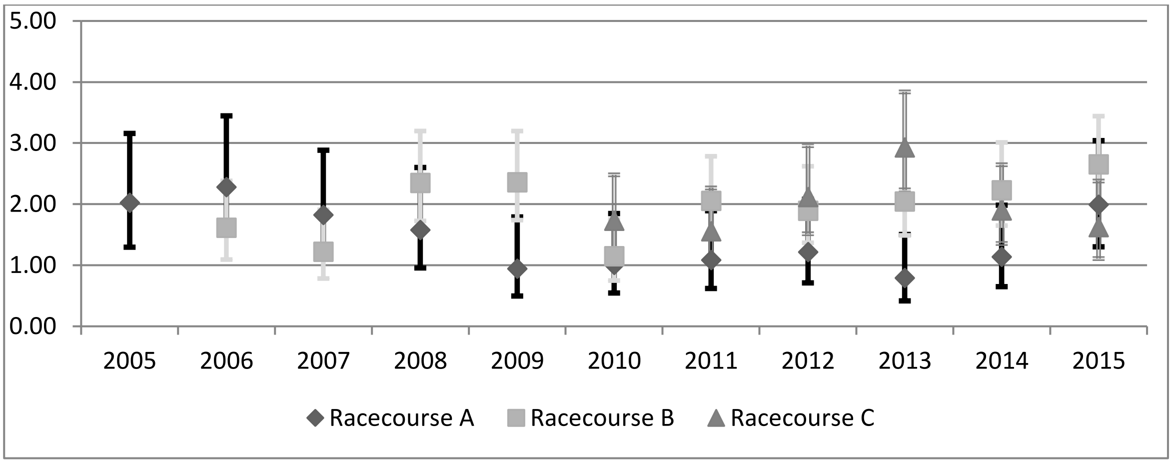

Figure 2-1: Figure showing the frequency of MSI per 1000 starts each year for the three different OSAF racecourses. (With error bars indication 95% CI)

2.3.3 Causes of MSI

Fatal or non-fatal MSI were recorded as fractures (exposed and non-exposed), tendon and ligament injuries and or joint luxation (exposed and non-exposed). The frequencies of these three broad categories of MSI at the three OSAF racecourses included in this study are shown in Figure 2-2, and detailed in Table 2-3. Fractures comprised the majority of MSI on all three racetracks. On Racecourses A and B tendon and ligament injuries were more common than joint luxations. However, on Racecourse C the reverse was true with luxations being more common than tendon and ligament injury.

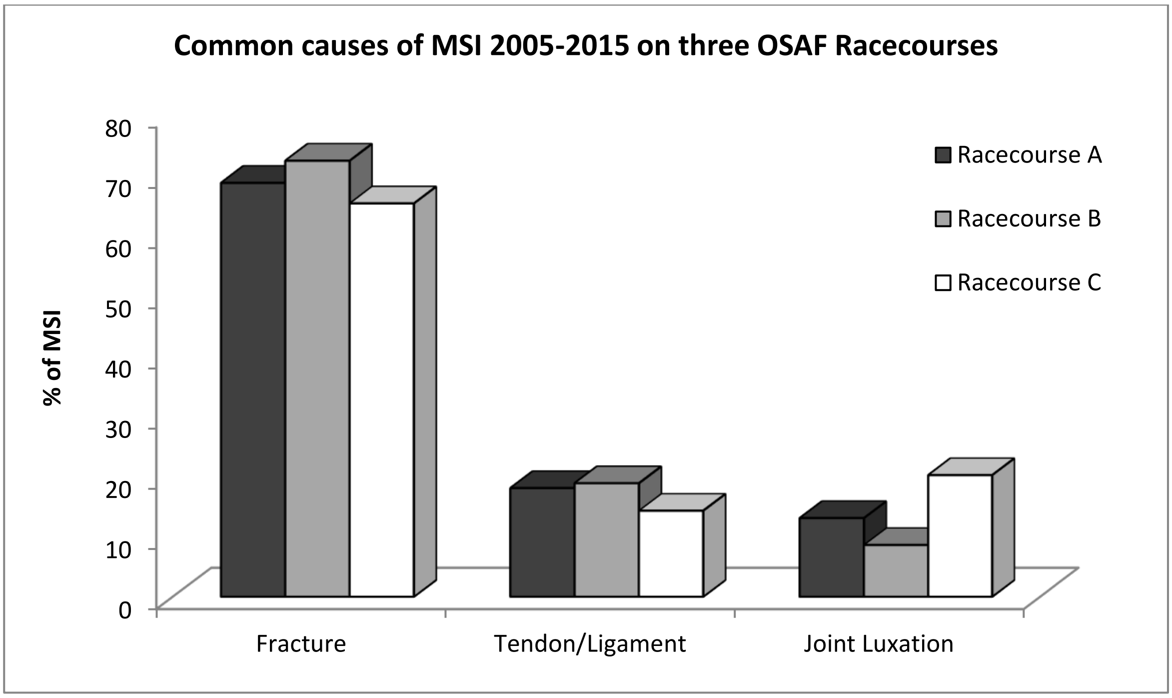

Figure 2-2: Frequency of the different causes of MSI as percentage cause of total MSI.

Table 2-3: The risk of each major category of MSI on each racecourse during study period, with 95% CI.

	A	B	C	A+B+C
Period	2005-2015	2006-2015	2010-2015	2005-2015
Starts	112188	181324	101869	395381
MSI (per 1000 starts)	160 (1.43)	359 (1.98)	202 (1.98)	721 (1.82)
Fracture (per 1000 starts)	110 (0.98)	260 (1.43)	132 (1.30)	502 (1.27)
Tendon/Ligament (per 1000 starts)	29 (0.26)	68 (0.38)	29 (0.28)	126 (0.32)
Luxations (per 1000 starts)	21 (0.19)	31 (0.17)	41 (0.40)	93 (0.24)

2.3.4 Risk factor analysis

2.3.4.1 Univariable analysis

Tables showing univariable analysis for categorical and continuous variables for the participating racecourses are shown in Tables 2-4, 2-5, 2-8, 2-9, 2-12, 2-13, 2-16, 2-17. AIC values for numerical variables as continuous or as categorical forms are shown in Tables 2-6, 2-10, 2-14 and 2-18, along with details of each continuous variable included in the model in its categorical form Tables 2-7, 2-11, 2-15 and 2-19. Results are described for each racecourse model and differences between them highlighted.

2.3.4.1.1 Racecourse “A”

Univariable analysis for Racecourse “A” comprised seven categorical variables (first start at the racecourse, the first year of the horse’s career, gender, authorized medication, previous injuries at the racetrack, season of the year and track status) and 11 continuous variables (age, age at first start, distance, cumulative distance raced, field size, horse weight, layups (a period of 60 days or more before the last race), layup days, starts between 0 and 90 days before the date of the MSI, starts between 90 and 180 days before the date of the MSI, career starts). The only continuous variable that had lower AIC in a categorical form was age, which was therefore retained in its 5-level categorical form.

Table 2-4: Univariable analysis for categorical variables. Racecourse "A"

Variable	Total n=112188	Cases n=160	Controls n=112028	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Female	40303	39	40264		REF			
Male	71885	121	71764	0.003	1.74	1.21	_	2.49
MEDICATION								
FB or Both (FF)	72763	117	72646		REF			
Not Medicated or FS	39425	43	39382	0.029	0.68	0.47	_	0.96
TRACK STATUS								
Good	91545	123	91422		REF			
Muddy	7526	13	7513	0.389	1.29	0.72	_	2.27
Wet	6498	11	6487	0.463	1.26	0.68	_	2.33
Heavy	6619	13	6606	0.193	1.46	0.82	_	2.59
FIRST YEAR CAREER								
No	53199	90	53109		REF			
Yes	58989	70	58919	0.026	0.70	0.51	_	0.95
FIRST START								
No	102077	145	101932		REF			
Yes	10111	15	10096	0.570	0.84	0.45	_	1.54
PREVIOUS INJURIES								
No	112169	160	112009		REF			
Yes	19	0	19	0.978	0.00	0.00	_	0.00
YEAR SEASON								
Autumn	23544	27	23517		REF			
Spring	22907	26	22881	0.970	0.99	0.57	_	1.69
Summer	41613	76	41537	0.038	1.59	1.02	_	2.47
Winter	24124	31	24093	0.665	1.12	0.66	_	1.87

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 2-5: Univariable analysis for continuous variables. Racecourse "A"

Variable	Pr(>|z|)	Odds Ratio	95% CI
DISTANCE Per extra meter	<0.001	1.00	1.00 _ 1.00
AGE Per extra year	0.001	1.21	1.07 _ 1.36
HORSE WEIGHT Per extra 10 kg	<0.001	1.11	1.00 _ 1.01
STARTS 0 to 90 days Per extra start	0.094	1.08	0.98 _ 1.17
STARTS 90 to 180 Per extra start	0.019	1.10	1.01 _ 1.18
TOTAL STARTS Per extra start	0.201	1.01	0.99 _ 1.02
AGE AT FIRST START Per extra year	0.024	1.22	1.02 _ 1.45
FIELD SIZE Per extra competitor	0.280	1.04	0.97 _ 1.10
CUMULATIVE DISTANCE RACED Per extra meter	0.118	1.00	1.00 _ 1.00
LAYUPS Per extra layup	0.537	1.03	0.93 _ 1.14
LAYUP DAYS Per extra 15 day	0.050	1.01	1.00 _ 1.00

Table 2-6: Compared AIC values. Racecourse "A"

VARIABLE	AIC as continuous	AIC as categorical
AGE	2410.959	2405.559
AGE AT FIRST START	2415.954	2416.622
JOCKEY WEIGHT	2418.353	2420.189
DISTANCE	2405.477	2405.947
DIVIDEND	2419.486	2424.106
HORSE WEIGHT	2400.315	2400.423
JOCKEY RACE WEIGHT	2420.281	2423.645
LAYUPS	2420.281	2422.601
SCRATCHES	2417.917	2419.842
STARTS 90-180 DAYS	2415.36	2418.757
STARTS CAREER	2419.096	2423.047

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 2-7: Categorised continuous variables for the final model. Racecourse "A"

	Total n=112188	Cases n=160	Controls n=112028	Pr(>|z|)	Odds Ratio	95% CI
AGE (years old)						
2	8157	1	8156	0.011	0.08	0.01 _ 0.54
3	37376	46	37330	0.165	0.76	0.51 _ 1.12
4	35844	58	35786		REF	
5	19396	33	19363	0.818	1.05	0.68 _ 1.61
6 or more	11415	22	11393	0.485	1.19	0.72 _ 1.94

2.3.4.1.2 Racecourse “B”

Univariable analysis for Racecourse “B” comprised 11 categorical variables (time of day, first start at the racecourse, the first year of the horse’s career, gender, authorized medication, previous injuries at the racetrack, race type, season of the year, racing surface, track configuration and track status) and 16 continuous variables (age, age at first start, distance, cumulative distance raced, field size, horse weight, layups, layup days, scratches, speed of winning horse, dividend, starts between 0 and 90 days before the date of the MSI, starts between 90 and 180 days before the date of the MSI, career starts, jockey weight, jockey race weight). Age, jockey weight, jockey race weight, cumulative distance, scratches, speed and total amount of starts were retained for further modelling as categorical variables. Age, cumulative distance raced, speed of the winning horse and career starts were all retained as a 5-level variables; jockey weight (the real weight of the Jockey) and jockey race weight (the actual weight that carries the horse during the race) were binary (< or ≥ 57Kg); and number of previous scratches was retained as a 3-level variable (0, 1 or 2 or more).

Table 2-8: Univariable analysis for categorical variables. Racecourse "B"

Variable	Total n=181324	Cases n=359	Controls n=180965	Pr(>|z|)	Odds Ratio	95% CI
GENDER						
Female	77171	111	77060		REF	
Male	104153	248	103905	<0.001	1.66	1.32 - 2.07
MED CATION						
FB or Both (FF)	126234	308	125926		REF	
Not Medicated or FS	55090	51	55039	<0.001	0.38	0.28 - 0.51
FIRST START						
No	148853	308	148545		REF	
Yes	32471	51	32420	0.068	0.76	0.56 - 1.02
PREVIOUS INJURIES						
No	181205	359	180846		REF	
Yes	119	0	119	0.962	0.00	0.00 - 0.00
YEAR SEASON						
Autumn	47829	99	47730		REF	
Spring	46036	88	45948	0.587	0.92	0.69 - 1.23
Summer	41796	70	41726	0.175	0.81	0.60 - 1.10
Winter	45663	102	45561	0.588	1.08	0.82 - 1.42
SURFACE						
Dirt	104228	266	103962		REF	
Turf	77096	93	77003	<0.001	0.47	0.37 - 0.60
TIME OF DAY						
After 6 pm	101356	218	101138		REF	
Before 6 pm	79968	141	79827	0.066	0.82	0.66 - 1.01
RACE TYPE						
Group	4977	2	4975		REF	
Listed & Non Grade	3050	5	3045	0.093	4.08	0.79 - 21.06
Other	173297	352	172945	0.022	5.06	1.26 - 20.33
FIRST YEAR CAREER						
No	95082	227	94855		REF	
Yes	86242	132	86110	<0.001	0.64	0.52 - 0.79
TRACK STATUS						
Wet	17389	23	17366		REF	
Normal	146906	297	146609	0.908	1.04	0.57 - 1.88
Heavy	17029	39	16990	0.706	0.85	0.37 - 1.97
TRACK CONFIGURATION						
Diagonal	22515	23	22492		REF	
Straight	84157	163	83994	0.004	1.9	1.23 - 2.94
Turn	74652	173	74479	<0.001	2.27	1.47 - 3.51

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 2-9: Univariable analysis for continuous variables. Racecourse "B"

Variable	Pr(>|z|)	Odds Ratio	95% CI		
DISTANCE					
Per extra 1000 meters	0.015	1.05	1.00	_	1.00
AGE					
Per extra year	<0.001	1.36	1.24	_	1.47
JOCKEY RACE WEIGHT					
Per extra kg	0.840	0.99	0.91	_	1.07
JOCKEY WEIGHT					
Per extra Kg	0.847	1.00	0.96	_	1.03
HORSE WEIGHT					
Per extra 10 kg	<0.001	1.07	1.00	_	1.01
DIVIDEND					
Per extra unit	0.823	1.00	0.99	_	1.00
SCRATCHES					
Per extra scratch	<0.001	1.26	1.13	_	1.40
CAREER STARTS					
Per extra start	0.001	1.03	1.01	_	1.04
STARTS 0 to 90 days					
Per extra start	0.127	1.06	0.98	_	1.15
STARTS 90 to 180 days					
Per extra start	0.051	1.08	1.00	_	1.16
AGE AT FIRST START					
Per extra year	<0.001	1.30	1.15	_	1.47
FIELD SIZE					
Per extra competidor	0.151	1.03	0.99	_	1.06
CUMULATIVE DISTANCE RACED					
Per extra 500 meter	0.001	1.01	1.00	_	1.00
LAYUPS					
Per extra layup	<0.001	1.13	1.06	_	1.20
SPEED OF WINNING HORSE					
Per extra k/h	0.056	0.99	0.97	_	1.00
LAYUP DAYS					
Per extra 15 days	<0.001	1.01	1.00	_	1.00

Table 2-10: Compared AIC values. Racecourse "B"

VARIABLE	AIC as continuous	AIC as categorical
AGE	5140.9	5134.101
AGE AT FIRST START	5173.98	5177.044
JOCKEY WEIGHT	5190.577	5186.588
CUMULATIVE DISTANCE RACED	5180.555	5179.134
DISTANCE	5185.029	5190.352
DIVIDEND	5190.561	5194.035
FIELD SIZE	5188.546	5192.78
HORSE WEIGHT	5171.707	5171.821
JOCKEY RACE WEIGHT	5190.572	5178.642
LAYUP DAYS	5169.343	5177.634
LAYUPS	5175.681	5181.498
SCRATCHES	5175.941	5175.388
SPEED OF WINNING HORSE	5186.666	5185.996
STARTS 0-90 DAYS	5188.333	5190.364
STARTS 90-180 DAYS	5186.956	5187.153
CAREER STARTS	5180.103	5176.663

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 2-11: Categorised continuous variables for the final model. Racecourse "B"

Variable	Total 181324	Cases 359	Controls 180965	Pr(>|z|)	Odds Ratio	95% CI		
AGE (years old)								
2	9025	7	9018	0.026	0.42	0.19	_	0.89
3	49693	53	49640	0.001	0.58	0.41	_	0.80
4	58908	109	58799		REF			
5	41545	122	41423	<0.001	1.59	1.22	_	2.05
6 or more	22153	68	22085	0.001	1.66	1.22	_	2.25
JOCKEY WEIGHT								
Less than 57 Kg.	105474	190	105284	0.044	0.81	0.65	_	0.99
57 Kg or more	75850	169	75681		REF			
CUMULATIVE DISTANCE RACED								
≤2200	39034	59	38975	0.024	0.68	0.48	_	0.95
2200> to ≤4200	35608	54	35554	0.030	0.68	0.48	_	0.96
420> to ≤7300	34527	77	34450		REF			
730> to ≤13100	35930	73	35857	0.568	0.91	0.66	_	1.25
>13100	36225	96	36129	0.259	1.19	0.88	_	1.60
JOCKEY RACE WEIGHT								
Less than 57 Kg	77805	122	77683	0.001	0.68	0.55	_	0.85
57 kg or more	103519	237	103282		REF			
SCRATCHES								
No scratches	131768	226	131542		REF			
1	35995	91	35904	0.002	1.48	1.15	_	1.88
2 or more	13561	42	13519	<0.001	1.81	1.30	_	2.51
SPEED OF WINNING HORSE k/h								
≤38.6	36500	91	36409	0.166	1.24	0.91	_	1.69
38.6>-≤39.3	36156	55	36101	0.121	0.76	0.53	_	1.07
39.3>-≤40.9	36390	73	36317		REF			
40.9>-≤ 42.5	36113	78	36035	0.650	1.08	0.78	_	1.48
>42.5	36165	62	36103	0.363	0.85	0.60	_	1.19
CAREER STARTS								
0 or 1	57447	82	57365	0.021	0.70	0.51	_	0.94
2	20035	37	19998	0.615	0.91	0.61	_	1.33
3 to 5	41190	84	41106		REF			
6 to 9	29829	65	29764	0.688	1.07	0.77	_	1.47
more than 9	32823	91	32732	0.042	1.36	1.01	_	1.83

2.3.4.1.3 Racecourse “C”

Univariable analysis for Racecourse “C” comprised 10 categorical variables (time of day, gender, authorized medication, previous injuries at the racetrack, race type, season of the year, racing surface, track, track configuration and track status) and 14 continuous variables (age, distance, cumulative distance raced, field size, horse weight, layups, layup days, scratches, speed of the winning horse, starts between 0 and 90 days before the date of the MSI, starts between 90 and 180 days before the date of the MSI, career starts, jockey weight, jockey race weight. Jockey weight, scratches and starts between 0 and 90 days before the date of the MSI were retained for further modelling as binary categorical variables.

Table 2-12: Univariable analysis for categorical variables. Racecourse "C"

Variable	Total n=101869	Cases n=202	Controls n=101667	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Male	62890	146	62744		REF			
Female	38979	56	38923	0.002	0.62	0.45	_	0.84
AUTHORIZED MEDICATION								
FB or Both (FF)	67516	149	67367		REF			
Not Medicated or FS	34353	53	34300	0.025	0.70	0.51	_	0.95
FIRST START								
No	79205	155	79050		REF			
Yes	22664	47	22617	0.727	1.06	0.76	_	1.46
PREVIOUS INJURIES								
No	101667	200	101467		REF			
Yes	202	2	200	0.023	5.07	1.25	_	20.56
YEAR SEASON								
Autumn	26557	64	26493		REF			
Spring	25461	55	25406	0.551	0.90	0.62	_	1.28
Summer	22655	33	22622	0.019	0.60	0.39	_	0.91
Winter	27196	50	27146	0.151	0.76	0.52	_	1.10
TRACK								
Dirt with turn	57935	111	57824		REF			
Dirt straight	39832	82	39750	0.621	1.07	0.80	_	1.43
Turf with turn	4102	9	4093	0.695	1.15	0.58	_	2.26
TRACK CONFIGURATION								
Straight	39832	82	39750		REF			
Turn	62037	120	61917	0.663	0.94	0.70	_	1.24
SURFACE								
Dirt	97767	193	97574		REF			
Turf	4102	9	4093	0.756	1.11	0.56	_	2.17
TIME OF DAY								
After 6	53657	108	53549		REF			
Before 6	48212	94	48118	0.821	0.97	0.73	_	1.27
TRACK STATUS								
Muddy	1086	3	1083		REF			
Wet	8595	20	8575	0.781	0.84	0.25	_	2.83
Normal	81552	152	81400	0.499	0.67	0.21	_	2.11
Heavy	10636	27	10609	0.889	0.92	0.27	_	3.03
RACE TYPE								
Other	97650	190	97460		REF			
Group graded	3134	9	3125	0.253	1.48	0.75	_	2.88
Listed & Non graded	1085	3	1082	0.546	1.42	0.45	_	4.45

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 2-13: Univariable analysis for continuous variables. Racecourse "C"

Variable	Pr(>|z|)	Odds Ratio	95% CI		
AGE					
Per extra year	0.002	1.19	1.06	-	1.33
HORSE WEIGHT					
Per extra 10 Kg	<0.001	1.14	1.00	-	1.01
JOCKEY WEIGHT					
Per extra Kg	0.358	1.04	0.95	-	1.12
SCRATCHES					
Per extra 3 scratches	0.967	1.01	0.80	-	1.25
DISTANCE					
Per extra 100 meters	0.035	1.05	1.00	-	1.00
CAREER STARTS					
Per extra start	0.402	0.99	0.95	-	1.01
STARTS 0 to 90 days					
Per extra start	0.781	1.02	0.90	-	1.13
STARTS 90 to 180 days					
Per extra start	0.708	0.98	0.86	-	1.10
FIELD SIZE					
Per extra 3 horses	0.876	1.01	0.95	-	1.05
CUMULATIVE DISTANCE RACED					
Per extra meter	<0.001	1.10	1.04	-	1.16
LAYUPS					
Per extra layup	0.620	1.03	0.92	-	1.13
SPEED OF WINNING HORSE					
Per extra Km/h	0.205	0.85	0.65	-	1.09
LAYUP DAYS					
Per extra 15 days	0.127	1.01	1.00	-	1.00
JOCKEY RACE WEIGHT					
Per extra kg	0.009	1.16	1.03	-	1.28

Table 2-14: Compared AIC values. Racecourse "C"

VARIABLE	AIC as continuous	AIC as categorical
AGE	2912.529	2913.587
JOCKEY WEIGHT	2920.891	2912.867
CUMULATIVE DISTANCE RACED	2921.542	2923.672
DISTANCE	2917.5878	2921.267
FIELD SIZE	2921.738	2926.788
HORSE WEIGHT	2882.011	2887.577
JOCKEY RACE WEIGHT	2914.791	2914.737
LAYUP DAYS	2919.554	2922.409
LAYUPS	2921.52	2921.591
SCRATCHES	2921.76	2920.984
SPEED OF WINNING HORSE	2920.142	2925.887
STARTS 0-90 DAYS	2921.685	2921.6
STARTS 90-180 DAYS	2921.62	2923.735
CAREER STARTS	2921.022	2927.05

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 2-15: Categorised continuous variables. Racecourse "C"

Variable	Total n=101869	Cases n=202	Controls n=101667	Pr(>|z|)	Odds Ratio	95% CI		
JOCKEY WEIGHT								
Less than 57 Kg	61985	102	61883	0.003	0.66	0.49	_	0.86
57 kg or more	39884	100	39784		REF			
JOCKEY RACE WEIGHT								
Less than 57 kg	53353	87	53266	0.008	0.69	0.52	_	0.90
57 Kg or more	48516	115	48401		REF			
SCRATCHES								
None	79796	153	79643		REF			
1 or more	22073	49	22024	0.372	1.16	0.83	_	1.59
STARTS 0 to 90 DAYS								
None	43280	83	43197		REF			
1 or more	58589	119	58470	0.688	0.61	1.15	_	0.52

2.3.4.1.4 Racecourse “B + C”

A model was built combining data from racecourses B and C in order to improve statistical power. This racecourses where chosen to be combined since they belong to the same country in the OSAF jurisdiction. New risk factors for the country were identified by combining information from these two important racecourses. Univariable analysis for Racecourses “B+C” comprised eight categorical variables (time of day, first start at one of the racecourses, gender, authorized medication, previous injuries, season of the year, surface and track configuration) and 15 continuous variables (age, distance, cumulative distance raced, field size, horse weight, layups, layup days, speed of winning horse, starts between 0 and 30 days before the date of the MSI, starts between 30 and 60 days before the date of the MSI, starts between 60 and 90 days before the date of the MSI, starts between 90 and 180 days before the date of the MSI, career starts, jockey weight, jockey race weight). Age, jockey weight jockey race weight, speed and starts between 30 and 60 days before the date of the MSI were retained for further modelling as categorical variables. Age and speed were retained as 5-level categorical variables, whereas jockey weight, jockey race weight and starts between 30 and 60 days were retained as binary variables.

Table 2-16: Univariable analysis for categorical variables. Racecourse "B+C"

Variable	Total n=283193	Cases n=561	Controls n=282632	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Male	167043	394	166649		REF			
Female	116150	167	115983	<0.001	0.61	0.50	-	0.73
AUTHORIZED MEDICATION								
FB or Both (FF)	193750	457	193293		REF			
Not Medicated or FS	89443	104	89339	<0.001	0.49	0.39	-	0.60
FIRST START								
No	244885	494	244391		REF			
Yes	38308	67	38241	0.273	0.87	0.67	-	1.11
PREVIOUS INJURIES								
No	282624	558	282066		REF			
Yes	569	3	566	0.090	2.68	0.85	-	8.35
YEAR SEASON								
Autumn	74386	163	74223		REF			
Spring	71497	143	71354	0.425	0.91	0.72	-	1.14
Summer	64451	103	64348	0.012	0.73	0.56	-	0.93
Winter	72859	152	72707	0.663	0.95	0.76	-	1.18
SURFACE								
Dirt	201995	459	201536		REF			
Turf	81198	102	81096	<0.001	0.55	0.44	-	0.68
TRACK CONFIGURATION								
Straight	123989	245	123744		REF			
Diagonal (SI)	22515	23	22492	0.002	0.52	0.33	-	0.79
Turn	136689	293	136396	0.347	1.08	0.91	-	1.28
TIME OF DAY								
After 6	155013	326	154687		REF			
Before 6	128180	235	127945	0.108	0.87	0.73	-	1.03

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 2-17: Univariable analysis for continuous variables. Racecourse "B+C"

Variable	Pr(>|z|)	Odds Ratio	95% CI
DISTANCE			
Per extra 100 meter	0.002	1.05	1.00 – 1.00
AGE			
Per extra year	<0.001	1.30	1.21 – 1.38
HORSE WEIGHT			
Per extra 10 Kg	<0.001	1.10	1.00 – 1.01
CAREER STARTS			
Per extra 3 starts	0.029	1.04	1.00 – 1.02
FIELD SIZE			
Per extra 3 horses	0.218	1.06	0.98 – 1.05
CUMULATIVE DISTANCE RACED			
Per extra 1000 meters	0.013	1.01	1.00 – 1.00
LAYUPS			
Per extra layup	0.010	1.07	1.01 – 1.12
LAYUP DAYS			
Per extra 10 days	<0.001	1.01	1.00 – 1.00
SPEED OF WINNING HORSE			
Per extra 5 Km/h	0.207	0.98	0.98 – 1.00
STARTS 0-30 days			
Per extra start	0.601	1.04	0.90 – 1.18
STARTS 30-60 days			
Per extra start	0.167	1.08	0.96 – 1.21
STARTS 60-90 days			
Per extra start	0.287	1.07	0.94 – 1.20
STARTS 90-180 days			
Per extra start	0.562	1.02	0.96 – 1.07
JOCKEY RACE WEIGHT			
Per extra Kg	0.145	1.05	0.98 – 1.12
JOCKEY WEIGHT			
Per extra Kg	0.786	0.99	0.95 – 1.04

Table 2-18: Compared AIC values. Racecourse "B+C"

Variables	AIC as continuous	AIC as categorical
AGE	8052.639	8043.278
CUMULATIVE DISTANCE RACED	8102.737	8104.363
DISTANCE	8098.88	8104.874
FIELD SIZE	8106.88	8111.439
HORSE WEIGHT	8055.679	8058.445
JOCKEY WEIGHT	8107.341	8097.181
JOCKEY RACE WEIGHT	8106.259	8089.571
LAYUP DAYS	8086.376	8095.837
LAYUPS	8102.057	8103.592
SPEED OF WINNING HORSE	8106.797	8106.221
STARTS 0-30 DAYS	8108.127	8108.145
STARTS 30-60 DAYS	8106.519	8105.047
STARTS 60-90 DAYS	8107.284	8107.559
STARTS 90-180 DAYS	8108.066	8108.382
CAREER STARTS	8103.899	8106.27

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 2-19: Categorised continuous variables for the final model. Racecourse "B+C"

Variable	Total n=283193	Cases n=561	Controls n=282632	Pr(>|z|)	Odds Ratio	95% CI		
AGE (years old)								
2	14269	11	14258	0.005	0.42	0.22	_	0.76
3	77931	98	77833	0.002	0.68	0.52	_	0.87
4	91788	170	91618		REF			
5	64010	183	63827	<0.001	1.55	1.25	_	1.90
6 or more	35195	99	35096	0.001	1.52	1.18	_	1.94
JOCKEY WEIGHT								
Less than 57 Kg	167212	292	166920	0.001	0.75	0.63	_	0.88
57 kg or more	115981	269	115712		REF			
JOCKEY RACE WEIGHT								
Less than 57 Kg	131158	209	130949	<0.001	0.69	0.57	_	0.81
57 Kg or more	152035	352	151683		REF			
SPEED Km/h								
≤39	57161	127	57034	0.729	0.96	0.75	_	1.22
39> to ≤ 41	56303	99	56204	0.037	0.76	0.58	_	0.98
41> to ≤ 59.4	56471	131	56340		REF			
59.4> to ≤62.2	56646	100	56546	0.040	0.76	0.58	_	0.98
>62.2	56612	104	56508	0.075	0.79	0.61	_	1.02
STARTS 30 to 60 DAYS								
No starts	156282	288	155994		REF			
1 and more	126911	273	126638	0.067	1.17	0.98	_	1.37

2.3.4.2 Multivariable Analysis

A total of three variables were found to be significantly associated with MSI in Racecourse “A”, while six were identified for MSI at Racecourses “B”, seven for MSI at Racecourse “C” and nine for MSI at the combination of Racecourses “B + C”. Final models are shown in Tables 2-20 to 2-23.

2.3.4.2.1 Racecourse “A”

Variables that were found to be associated with increased odds of MSI in flat racing at Racecourse “A” were: horse weight, race distance, age. Heavier horses had greater odds of MSI than lighter horses (Odds Ratio (OR) 1.1, 95% C.I. 1.05-1.15 per extra 10 kilograms). Horses competing in longer distance races had greater odds of MSI (OR 1.1, 95% C.I. 1.04-1.016 per extra 100 meters).

The variable that was found to be associated with decreased odds of MSI in flat racing at Racecourse “A” was age. Two year old horses had lower odds of MSI than four year old horses (OR 0.1, 95% C.I. 0.01-0.7). There was no statistically significant difference in the likelihood of MSI for any horses aged 3-years or more. Other variables (season and field size) were retained within the model, due to the fact that they resulted in a moderate improvement in the overall fit of the model as measured by AIC.

Table 2-20: Multivariable logistic regression model for MSI in Racecourse A.

Variable	Pr(>|z|)	Odds Ratio	95% CI
HORSE WEIGHT			
Per extra 10 Kilograms	<0.001	1.10	1.05 - 1.15
DISTANCE			
Per extra 100 meters	<0.001	1.10	1.04 - 1.16
AGE (years old)			
2	0.021	0.10	0.01 - 0.70
3	0.223	0.78	0.53 - 1.16
4		REF	
5	0.967	1.01	0.66 - 1.55
6 or more	0.687	1.11	0.68 - 1.81
YEAR SEASON			
Autumn		REF	
Spring	0.559	0.85	0.49 - 1.46
Summer	0.096	1.46	0.94 - 2.26
Winter	0.831	0.94	0.56 - 1.59
FIELD SIZE			
Per extra horse	0.143	1.05	0.98 - 1.12

2.3.4.2.2 Racecourse “B”

Variables that were found to be associated with increased or decreased odds of MSI in flat racing at Racecourse “B” were: age, racing surface, horse weight, gender, declared authorized. As regards age, 5-year old horses had greater odds of MSI than 4-year old horses (O.R 1.41, 95% C.I. 1.07-1.86). There was no statistically significant difference in the likelihood of MSI for any horses aged 2-, 3- and 6-years or more. Running on turf represented a lower risk than running on dirt (O.R 0.53, 95% C.I. 0.39-0.7). Heavier horses had an increased odds of MSI than lighter horses (Odds Ratio (OR) 1.05, 95% C.I. 1.01-1.08 per extra 10 kilograms). Males had an increased odds of MSI than females (OR 1.37, 95% C.I. 1.08-1.74). Declared authorized medication was also significant in this final model. Horses that were declared to run medicated with phenylbutazone (FB) and/or phenylbutazone and furosemide (FF) had greater odds of suffering an MSI than horses running with furosemide (FS) or without any medication (O.R 1.79, 95% C.I. 1.16-2.78).

Several other variables (medication running speed, jockey weight, first year career, scratches, race distance, and field size) were retained within the model, due to the fact that they resulted in a moderate improvement in the overall fit of the model as measured by AIC. These were speed of winning horse, jockey weight, first year in the career of the horse, number of scratches, race distance and field size.

Table 2-21: Multivariable logistic regression model for MSI in Racecourse B.

Variable	Pr(>|z|)	Odds Ratio	95% CI
AGE (years old)			
2	0.612	0.78	0.31 – 2.01
3	0.165	0.69	0.41 – 1.17
4		REF	
5	0.013	1.41	1.07 – 1.86
6 or more	0.202	1.26	0.88 – 1.80
SURFACE			
Dirt		REF	
Turf	<0.001	0.53	0.39 – 0.70
HORSE WEIGHT			
Per extra 10 Kg	0.007	1.05	1.01 – 1.08
GENDER			
Female		REF	
Male	0.010	1.37	1.08 – 1.74
AUTHORIZED MEDICATION			
FS or None		REF	
FB or FF	0.008	1.79	1.16 – 2.78
SPEED (Kilometers per hour)			
≤38.6	0.185	1.23	0.90 – 1.68
38.6>-≤39.3	0.170	0.78	0.55 – 1.11
39.3>-≤40.9		REF	
40.9>-≤ 42.5	0.631	1.08	0.78 – 1.50
>42.5	0.061	1.43	0.98 – 2.09
JOCKEY WEIGHT			
More than 57 Kg		REF	
Less than 57 Kg	0.089	1.31	0.96 – 1.80
FIRST YEAR CAREER			
No		REF	
Yes	0.065	1.30	0.98 – 1.71
SCRATCHES			
None		REF	
1	0.064	1.27	0.99 – 1.63
2 or more	0.083	1.36	0.96 – 1.91
DISTANCE			
Per extra 100 meters	0.070	1.04	1.00 – 1.11
FIELD SIZE			
Per extra horse	0.140	1.03	0.99 – 1.07

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

2.3.4.2.3 Racecourse "C"

Variables that were found to be associated with increased or decreased odds of MSI in flat racing at Racecourse "C" were: horse weight, race distance, track configuration, previous injuries at the track, total amount of starts in the horse's career, age and season of the year. Heavier horses had greater odds off suffering a MSI than lighter horses (O.R 1.13, 95% C.I. 1.08-1.17 every extra 10 kilograms). Horses running longer distance had greater odds of suffering a MSI (O.R 1.08, 95% C.I. 1-1.11 per extra 100 meters). Horses running in races with a turn had lower odds of MSI than those running in races that were straight (O.R 0.51, 95% C.I. 0.31-0.83). Odds of MSI were also bigger for horses that had suffered from a previous injury on the same racetrack (O.R 5.66, 95% C.I. 1.38-23.26). Horses that had more starts also had lower odds of MSI (O.R. 0.96, 95% C.I. 0.92-0.99 per extra start). The odds of MSI increased per extra year of age of the horse (O.R 1.19, 95% C.I. 1.04-1.35). As regards the season of the year, summer, winter racing was found to be less risky than autumn racing (O.R 0.58, 95% C.I. 0.38-0.89 for summer and O.R 0.65, 95% C.I. 0.45-0.95 for winter).

Other variables (speed of winning horse and jockey weight) were retained within the model, due to the fact that they resulted in a moderate improvement in the overall fit of the model as measured by AIC.

Table 2-22: Multivariable logistic regression model for MSI in Racecourse C.

Variable	Pr(>|z|)	Odds Ratio	95% CI
HORSE WEIGHT			
Per extra 10 Kilograms	<0.001	1.13	1.08 - 1.17
JOCKEY WEIGHT			
More than 57 kg		REF	
Less than 57 Kg	0.086	0.78	0.59 - 1.04
DISTANCE			
Per extra 100 meters	0.034	1.08	1.00 - 1.11
TRACK CONFIGURATION			
Straight		REF	
Turn	0.007	0.51	0.31 - 0.83
SPEED			
Per extra kilometre per hour	0.117	0.70	0.45 - 1.09
PREVIOUS INJURIES			
No		REF	
Yes	0.016	5.66	1.38 - 23.26
CAREER STARTS			
Per extra start	0.013	0.96	0.92 - 0.99
AGE			
Per extra year	0.010	1.19	1.04 - 1.35
YEAR SEASON			
Autumn		REF	
Spring	0.262	0.81	0.56 - 1.17
Summer	0.013	0.58	0.38 - 0.89
Winter	0.027	0.65	0.45 - 0.95

2.3.4.2.4 Racecourses B + C

Variables that were found to be associated with increased or decreased odds of MSI in flat racing at Racecourses “B + C” were: age, horse weight, racing surface, distance, gender, layups, declared authorized medication, season of the year and layup days. Five and 6-year old horses had grater odds of suffering an MSI than 4-year olds (O.R. 1.48, 95% C.I. 1.19-1.83 for five year-old and O.R. 1.4, 95% C.I. 1.06-1.86 for six year old). Two and 3-year old horses were at apparent reduced risk than 4-year olds but not statistically significantly so. Heavier horses had greater odds of suffering a MSI than lighter horses (O.R 1.07, 95% C.I. 1.04-1.09 per extra 10 kilograms). Horses running on turf had lower odds of MSI that those that ran on dirt (O.R 0.63, 95% C.I. 0.5-0.79). Longer races were more risky (O.R 1.06, 95% C.I. 1-1.1 per extra 100 meters). Female thoroughbreds had lower odds of MSI than stallions and geldings (O.R 0.77, 95% C.I. 0.64-0.94). Horses that took more layups had lower odds of MSI (O.R 0.87, 95% C.I. 0.79-0.95 per extra layup). As regards declared authorized medication, horses that ran having declared FB or FF had greater odds of suffering an MSI than horses that run using only FS or no medication at all (O.R. 1.45, 95% C.I. 1.03-2.04). Racing in the summer was less risky than racing in the autumn (O.R 0.72, 95% C.I. 0.56-0.92). As regards layup days, the odds for suffering MSI increased as horses had longer layup periods (O.R. 1.01, 95% C.I. 1.-1.02 per extra 15 days).

Other variables (speed of the winning horse and previous injuries) were retained within the model, due to the fact that they resulted in a moderate improvement in the overall fit of the model as measured by AIC.

Table 2-23: Multivariable logistic regression model for MSI in Racecourses B+C.

Variable	Pr(>|z|)	Odds Ratio	95% CI
AGE (years old)			
2	0.272	0.67	0.33 - 1.37
3	0.719	0.94	0.66 - 1.34
4		REF	
5	<0.001	1.48	1.19 - 1.83
6 or more	0.018	1.40	1.06 - 1.86
HORSE WEIGHT			
Per extra 10 Kg	<0.001	1.07	1.04 - 1.09
SURFACE			
Dirt		REF	
Turf	<0.001	0.63	0.50 - 0.79
DISTANCE			
Per extra 100 meters	0.002	1.06	1.00 - 1.11
GENDER			
Male		REF	
Female	0.008	0.77	0.64 - 0.94
LAYUPS			
Per extra layup	0.002	0.87	0.79 - 0.95
AUTHORIZED MEDICATION			
FS or None		REF	
FB or FF	0.034	1.45	1.03 - 2.04
YEAR SEASON			
Autumn		REF	
Spring	0.184	0.86	0.68 - 1.08
Summer	0.009	0.72	0.56 - 0.92
Winter	0.116	0.83	0.66 - 1.05
LAYUP DAYS			
Per extra 15 days	0.071	1.01	1.00 - 1.02
SPEED OF WINNING HORSE (Kilometers per hour)			
≤39	0.582	1.08	0.83 - 1.40
39> to ≤ 41	0.324	0.87	0.66 - 1.15
41> to ≤ 59.4		REF	
59.4> to ≤62.2	0.117	0.80	0.61 - 1.06
>62.2	0.491	1.12	0.81 - 1.57
PREVIOUS INJURIES			
No		REF	
Yes	0.098	2.62	0.84 - 8.22

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

2.3.4.2.5 Comparative results

Risk factors for MSI varied between the three OSAF racecourses. Some of them were common and were risk factors at more than one racecourse, whereas others were exclusive to just one of the racecourses. Table 2-24 shows the results for each racecourse, an X indicates that that variable was identified as a statistically significant risk factor for that racecourse. Horse weight, distance and age were common risk factors for all racetracks and for the combination for racecourse B+C. However, other important unique (less common) risk factors were also identified such as starting in a race under the use of phenylbutazone or season of the year.

Table 2-24: Comparative results for risk factors at the three OSAF racecourses.

MSI RESULTS				
	RACECOURSE			
VARIABLE	A	B	C	B+C
Horse weight	X	X	X	X
Distance	X	X	X	X
Age	X	X	X	X
Season of the year			X	X
Racing surface		X		X
Gender		X		X
Layups				X
Authorized Medication		X		X
Layup days				X
Race configuration			X	
Previous injuries			X	
Starts career			X	

2.4 Discussion

2.4.1 Risk Factors common to models for Racecourses A, B, C and Racecourses B+C

Horse weight

Horse weight was significantly associated with the risk of MSI in this investigation for all three OSAF participating racetracks, including the combination of Racecourse B and C that belong to the same Latin American country. For all racecourses the odds of suffering an MSI increased by between 5% and 13% for each 10 extra kilograms of weight. Horses that suffered from a fatal or non-fatal MSI might have run at an inappropriate body weight, this association and conclusion has been previously published for superficial flexor tendon injuries (Takahashi, et al., 2004). This result may also be explained by the fact that vertical ground reaction forces on the hind limbs increase when horses have added weight on their backs (Clayton, et al., 1999). The conclusion being that MSI could clearly be the result of that extra load to which horses are exposed on their forelimbs. However, one has to recognise that a horse carrying extra 'body' weight is likely to have very different biomechanics than a horse to which extra 'unnatural' weight has been added.

The fact that the appropriate detection of anabolic steroids was not fully accomplished in Latin America through this study period could also be related to this risk factor. Even though the use of any anabolic steroid is strictly forbidden in racing in Latin America, appropriate means to detect this substances in the anti-doping control were not available during the study period. It might be possible that many of these heavier horses could have been medicated with anabolic steroids. The effect of these substances on bone density and behaviour alterations could also influence the risk of MSI, further investigation including these variables should be done in the future.

Race distance

Results indicated that longer races were more likely to include MSI. For all racecourses the risk of MSI increased by between 4% and 10% for every extra 100 meters of race distance. This could be due to the fact that the horses in longer races spend more time at risk since they have to cover more ground (Parkin, et al., 2004b). Many studies had also demonstrated that an increase in the race distance resulted in a greater risk of suffering different outcomes considered as an MSI in this study: fatal fractures (Parkin, et al., 2004b), fatal lateral condylar fracture of the third metacarpus/metatarsus (Parkin, et al., 2005), any type of fatality (Henley, et al., 2006), (Boden, et al., 2007), superficial digital flexor tendon injuries (Takahashi, et al., 2004). It is also plausible that horses running longer distances are exposed to high-speed exercise for a longer time which would likely result in fatigue and potential breakdown of musculoskeletal structures. However, Parkin, et al. (2006a), when reviewing race videos to identify the exact part of the race at which fatal distal limb fractures occurred, was unable to detect a preponderance of fatal injuries toward the end of races, which one would expect to be the case if fatigue was truly a significant factor.

Age

Results related to the age of then horse varied amongst models in this study. The model for Racecourse A showed that 2-year olds were at reduced risk compared with 4-year olds. The model for Racecourse B demonstrated that 5-year olds were at increased risk than 4-year olds. The model for Racecourse C demonstrated a 19% increase in risk for each extra year of age. Finally, the final model for Racecourses B+C suggested that 5- and 6-year olds were at greater risk of suffering a MSI than 4-year old horses. In general these results indicate that older horses were at higher risk, but the exact relationship differs between horses racing at different tracks. Older horses will have trained and raced for a longer period and been exposed to the risk of suffering a (minor) MSI for a longer time and that (minor) MSI contributes to the risk of a significant subsequent MSI. Older horses might have been exposed to repetitive microtrauma, multiple micro fractures or subclinical injuries as a result of training or racing for a longer period (Riggs, 1999; Riggs, et al., 1999). Racehorses that receive treatment for orthopaedic conditions, that perhaps become more common with age, such as corticosteroids intraarticular injections, and continue training have a greater subsequent incidence of injury (Whitton, et al., 2014). Many studies prior to this one have already demonstrated that older horses are at greater risk of suffering an injury than younger horses. It was described as a risk factor for breakdown (Mohammed, et al., 1991), for fatal MSI, for injury to the superficial digital flexor tendon and suspensory apparatus (Perkins, et al., 2005a; Reardon, et al., 2012).

2.4.2 Risk factors common to Racecourse B and Racecourses B+C

Racing surface

Starts made on turf were associated with a 40-50% reduction in risk of MSI compared with starts made on dirt at both Racecourse B and Racecourse B+C models. This matches with studies suggesting that a possible explanation could be because turf is softer than dirt (Mohammed, et al., 1991; Georgopoulos & Parkin, 2016a and 2016b). This result would also concur with the theory that firmer going is riskier than soft (Parkin, et al., 2004b). Harder tracks have less cushioning effect so forces on the limbs are greater as the hoof impacts with the ground. It’s worth mentioning that we are not sure about cushioning differences between dirt and turf in these racecourses, since going is not measured in the same way on both surfaces (at least in Racecourse B). A ‘Going Stick’ is used on the turf track while the status of the dirt track is informed by its appearance (normal, wet, heavy). The fact that most races are run on dirt (201,995 races on dirt and 81,198 on turf for the study period for Racecourse B+C), could also indicate that the turf track is better preserved. It’s important to also mention that the turf track at racecourse C was only introduced near the end of 2011.

Further investigation is required to explain this result. Track preparation and composition are not always the same and watering and climatological effects also affect surface qualities that require validated measurement tools. The development of an equivalent method (to that of the ‘Going Stick’) for use on dirt surfaces would improve comparative information about our tracks for future investigations.

Gender

Gender of the horse was categorised as female or male. Information about gelding or entire male was not available in this study. Male horses were at 20% to 30% greater risk of suffering an MSI than female horses. It has been suggested that this could be to the willingness of owners to retire female horses from racing earlier than male horses when suffering from any type of injury, since females are usually wanted for breeding purposes (Perkins, et al., 2005a). Geldings or even entire males with no breeding value may be forced to continue running despite subclinical injury, simply because they have much reduced ‘value’ following the end of their racing career. Accumulation of injury or micro trauma in musculoskeletal structures might therefore result in males being at greater risk of MSI (Bailey, et al., 1999).

Other studies also reported an increase in the odds of injury in male horses compared with females, also arguing that this result may be due to the wish of owners to remove any injured female from racing for breeding purposes or for future sale (Estberg, et al., 1996b; Hernandez, et al., 2001; Boden, et al., 2007). The effect of sex hormones on bone density and bodyweight and differences in behaviour amongst stallions, geldings and mares may also influence the risk of fatality and should be considered in future investigations (Boden *et al.*, 2007).

The risk of superficial digital flexor tendon injury was higher for males than for females in Japanese studies (Takahashi, et al., 2004; Kasashima, et al., 2004). There are human studies that have also found sex related differences in risk of ligament and tendon injuries (Hewett, 2000; Aström, 1998; Kvist, 1994).

Declared Authorized Medication

Racing in Latin America varies as regards to authorized medication for race days. It is strictly forbidden to submit a horse to undergo any pharmacological treatment of any nature, except from those specifically authorised by the Racing Committee. On request, the use of monodrug medication whose active components are either furosemide (FS) or phenylbutazone (FB), is authorized. This authorization varies amongst Latin American countries and has been modified in the last few years. It will be detailed for the country to which Racecourse B and C belong, for FS and FB separately.

FS regulatory changes and actual status: Until the year 2012, FS was authorized in every race. In the year 2013 its use was banned in Group I and Group II races (most important races of the calendar). In the year 2014 its used was also banned in Group III and Listed raced (second most important races of the calendar).

FB regulatory change and actual status: Until the year 2009 FB was authorized for horses older than 3.5 years old, with the exception of Group Graded (Group I, II and III) and Listed races. In the year 2010 this changed and FB became forbidden in horses up to 4 years old and not only Group Graded and Listed races but in Non Grade Classic races as well (all Black Type races). Horses can be medicated with FB as long as they are 4 years old or older, and competing in non-Black Type Races.

For each horse that runs under any of these medications a declaration must be made prior to every race to the veterinary department, that notifies the Racing Authorities of the intention to run under one or both of these medications. Once this is declared it becomes public information for gamblers and stays in the racing system database.

For this study, information about authorized declared medication was categorized into two groups: A. Horses that had been declared to run using either FB or FF (phenylbutazone and furosemide); and B. horses that had been declared to run without medication or only with FS. Horses racing under the former conditions (i.e. FB or FF) were at significantly (30% to 40%) greater risk of MSI than those horses racing under the later conditions (FS or no medication). Table 2-25 shows frequency of MSI per 1000 starts and number of MSI per year in the different medication groups. This is also represented in Figure 2-3. With the exception of the year 2009; MSI prevalence has always been significantly lower in horses declared as racing with only FS or no medication compared with horses declared to run with FB or FF.

As far as we are aware, such association has not previously been demonstrated. The increased risk for the FB/FF group is probably due to the analgesic effect of this NSAID, enabling horses to continue to race in the presence of subclinical injuries and/or pain as a result of different pathologies. The continued use of FB may allow horses to continue training and racing accumulating subclinical and even clinical injuries or pathological changes in different musculoskeletal structures. Without FB it is probable that some of these horses would not be able to appear on the racecourse as pain associated with the reason for FB administration would impact on racing performance. It is obviously important to state that this result does not imply that the use of FB directly increases the risk of MSI. It is the fact that horses are able to race, and therefore at risk, while carrying subclinical pathology or mild lameness, that is the proposed causal association.

Table 2-25: Frequency of MSI per 1000 starts and number of MSI and starts per year in the different medication categories, with 95% CI.

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
TOTAL STARTS		15492	15545	17023	17384	18340	19967	19009	18604	18843	21117	181324
Racecourse B	FB or FF Starts	12156	12162	13473	13701	14002	12666	12211	11182	11731	12950	126234
	FB or FF MSI	**21**	**19**	**37**	**31**	**19**	**36**	**32**	**28**	**37**	**48**	**308**
	per 1000 starts	**1.73**	**1.56**	**2.75**	**2.26**	**1.36**	**2.84**	**2.62**	**2.5**	**3.15**	**3.71**	**2.44**
	95% CI	1.13-2.64	1-2.44	1.99-3.78	1.59-3.21	0.87-2.12	2.05-3.93	1.86-3.70	1.73-3.62	2.29-4.34	2.80-4.91	2.18-2.73
	FS or None Starts	3336	3383	3550	3683	4338	7301	6798	7422	7112	8167	55090
	FS or None MSI	**4**	**0**	**3**	**10**	**2**	**5**	**4**	**10**	**5**	**8**	**51**
	per 1000 starts	**1.2**	**0**	**0.85**	**2.72**	**0.46**	**0.68**	**0.59**	**1.35**	**0.7**	**0.98**	**0.93**
	95% CI	0.47-3.08	0-1.13	0.29-2.48	1.48-4.99	0.13-1.68	0.29-1.60	0.23-1.51	0.73-2.48	0.30-1.64	0.50-1.93	0.7-1.22
Racecourse B+C	FB or FF Starts	12156	12162	13473	13701	26951	24103	22729	22794	22519	23162	193750
	FB or FF MSI	**21**	**19**	**37**	**31**	**44**	**54**	**59**	**62**	**62**	**68**	**457**
	per 1000 starts	**1.73**	**1.56**	**2.75**	**2.26**	**1.63**	**2.24**	**2.6**	**2.72**	**2.75**	**2.94**	**2.36**
	95% CI	1.13-2.64	1-2.44	1.99-3-78	1.59-3.21	1.22-2.19	1.72-2.92	2.01-3.35	2.12-3.49	2.15-3.53	2.32-3.72	2.15-2.58
	FS or None Starts	3336	3383	3550	3683	8171	13191	12335	13563	14273	13958	89443
	FS or None MSI	**4**	**0**	**3**	**10**	**6**	**14**	**11**	**28**	**14**	**14**	**104**
	per 1000 starts	**1.2**	**0**	**0.85**	**2.72**	**0.73**	**1.06**	**0.89**	**2.06**	**0.98**	**1**	**1.16**
	95% CI	0.47-3.08	0-1.13	0.29-2-48	1.48-4.99	0.34-1.60	0.63-1.78	0.5-1.60	1.43-2.98	0.58-1.65	0.6-1.68	0.96-1.41

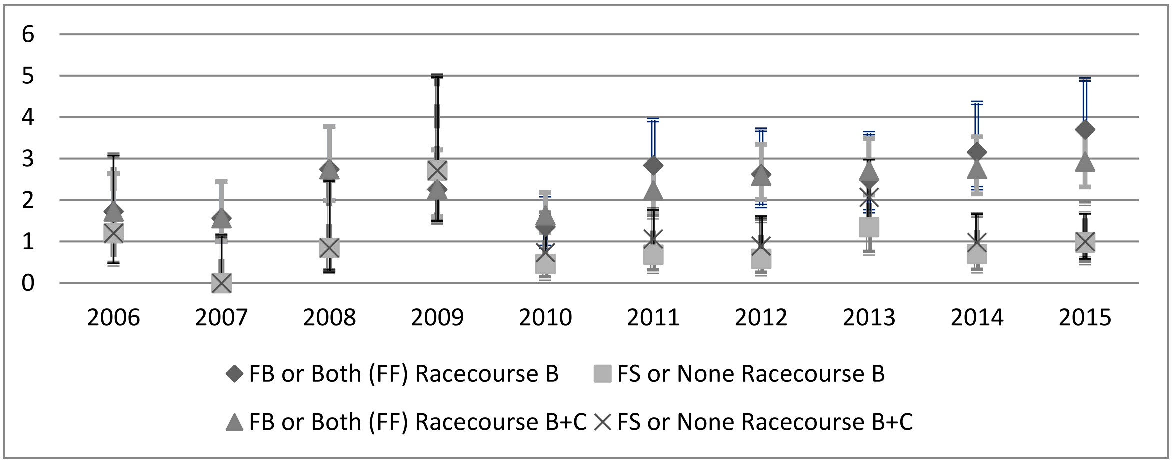

Figure 2-3: Figure showing the frequency of MSI per 1000 starts each year for the different medication categories. (With error bars indication 95% CI). FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

2.4.3 Risk factors common to Racecourse C and Racecourses B+C

Season of the year

The risk of MSI was reduced in summer and winter months compared to autumn. Other studies have also found associations between risk and season of the year. It was found that running in summer was riskier; in contrast to our study; for breakdowns (Mohammed, et al., 1991) and tendinopathy (Reardon, et al., 2012), this was found even when the going of the track was also taken into account which suggests that other season-related factors apart from firmness of ground are related to injury risk. It is important to comment that in the current study track status is described as normal, wet or heavy on dirt at least and is not measured with appropriate validated instruments. This result may therefore reflect a currently unmeasurable characteristic of the racing surface associated with season and that season is in fact a proxy measure for this factor. Perkins et al. (2005a) demonstrated that there was a reduced risk of injury during late winter and early spring, but also argued that seasonal effects are likely to be mediated through climate related factors, which if measured and included in models may remove any remaining apparent seasonal effect.

Factors such as rain, wind, humidity and level of evaporation can affect track condition and surface. Further investigation of different factors is required to determine which factors might best explain this result.

2.4.4 Other Risk factors for Racecourse C

Track configuration

Horses running in races with a turn were at reduced risk of MSI than horses running in entirely straight races at Racecourse C. Straight races at this racecourse were associated with an approximately 2-fold increase in risk of MSI. A previous survey indicated that most of the catastrophic injuries occur on fast tracks, in turns and during the stretch run to the finish (Hill, 2003). Evaluation of racing videos revealed that horses are more likely to be injured in a turn than on a straight line (Ueda, 1991). On the other hand, in one study by Peloso et al. (1994), the number of turns in the race (implying shorter races) was less for horses suffering catastrophic injuries.

In the current study, races with a turn are longer than straight races, and any confounding effect of distance of the race is already taken account of in the final models. Of course straight short races (up to 1000 meters) are probably the fastest races, speed of winning horse was also included in this particular model, but there was not enough information to measure the speed variable for each horse.

Therefore, this finding could also represent an effect of speed. Many injuries in our study occur a few meters before finish line or immediately after it, but this information was not taken into account when building the final model which could partly explain our results. Further investigation is required to explain this finding.

Previous injuries

Our results indicated that the odds of MSI are more than five times higher for horses that have sustained previous injuries during racing recorded by the veterinary service.

This result is consistent with many studies. It was found that the risk of sustaining a fracture was higher in a horse that entered the “veterinary list”, assessed to be at increased risk by regulatory veterinarians conducting pre-race examinations (Georgopoulos & Parkin, 2016b). Horses that had previously had SDF tendinopathy diagnosed at the racecourse were found to be approximately 20 times more likely to sustain another SDF lesion during racing (Reardon, et al., 2012). It has been suggested that many racehorse injuries are the product of long term insidious skeletal and soft tissue damage resulting from repeated loads during high speed exercise (Estberg, et al., 1995). Post mortem findings such as pre-fracture pathology seen commonly in horses that sustain fatal fractures also substantiate this result. Focal bone loss as a result of greater erosion surface could contribute to fracture propagation (Whitton, et al., 2013). Even though these two studies make reference to subclinical changes and not clinical recorded injuries, they support the fact that important MSI occur after previous damage, and that pre-existing pathologic conditions play an important role in racing injuries. It has been suggested that regulatory veterinarians can identify horses during prerace physical inspection that have an increased risk of injury during racing (Cohen, et al., 1997) and this is the goal of much of the epidemiological work in this area. There are studies focused on trying to identify subchondral bone and/or cartilage changes by the use of magnetic resonance; findings related to this may help prevent some catastrophic fractures (Tranquille, et al., 2012). It has been demonstrated that greater depth of dense subchondral/trabecular bone of the third metacarpus was associated with an increased likelihood of being from a horse that had sustained a fracture (Tranquille, et al., 2016).

It’s worth mentioning that records of previous injuries in racecourses in Latin America are very few and that these are confidential. We believe that if this information was shared between racecourses in the same regions hosting the same competitors, records would improve, as would results with the additional benefit of improving welfare.

Career starts

Our results indicate that risk of MSI decreased by about 4% for every extra start in the horse’s racing history. This could be explained by the fact that healthier horses are more likely to race more often (Mohammed, et al., 1991). A further study by Perkins et al. (2005a), also suggested that there was a progressive reduction in risk of injury to the SDFT as the number of starts in a preparation increased.

This result regarding racing history at Racecourse C should however be treated with some caution this variable only reflects starts at Racecourse C and there are other racecourses in the vicinity at which some racehorses will have no doubt competed. Many horses will therefore have had more starts than that which is recorded in Racecourse C data. Further investigation considering starts at Racecourse C and the two other nearby tracks is required to fully analyse this variable.

2.4.5 Other Risks factors for Racecourses B+C

Layup and Layup days

The odds of MSI decreased in horses that took layups (a period away from racing for at least 60 days), but increased as the length of the layup increased. The longer the period away from racing (over the initial 60 day period), the higher the risk of MSI when returning to competition.

A study by Estberg et al. (1998a) reported an association between intensive training and racing schedules with catastrophic MSI and layups in California Thoroughbred horses. It suggested that layup periods represented compulsory periods of recovery from injury. Another study by Hernandez et al. (2001) reported that horses with 33 or more days since their last race were 2.5 times more likely to have a catastrophic MSI during racing compared to horses with 13 or less days. These authors argued that horses with a pre-existing injury would be more likely to experience periods of reduced activity, have an extended intervals between races, and be at a higher risk of bone fracture. Additionally horses that return to racing or training after an extended period of reduced exercise (two month or more) may have insufficient bone mass to prevent microdamage with exercise and stress fractures may develop as a result of continued repetitive loading (Carrier, et al., 1998).

Our findings suggest that giving a horse appropriate rest (layup) may contribute to the healing of pre-existing injuries or may let bone or other musculoskeletal structures adapt. On the other hand, the fact that longer layup periods increase MSI risk could imply that more serious injuries may require not only longer resting periods but perhaps, the retirement of the competitors or more gradual phased return to full exercise.

It is worth mentioning that start data from one of the racecourse at which these competitors race was not available for this study. That would obviously modify layup or layup periods if they would have run in that racecourse in between racing at Racecourses B or C. It's also important to bear in mind that there are no record of official workouts, so data about what horses do on their layup periods is not available.

2.5 Limitations of this study

As previously stated a limitation of this study is the fact that starts information from different racecourses in which the same competitors run was not available. It is crucial to be certain about the number of starts a horse had in order to accurately analyse results regarding a horse's racing history and layups.

Lack of official training records is also a limitation of this study since having that information could help understand and explain some of our results, specifically by better representing the true exercise history of horses included in the study.

The fact that there may be some variability in veterinarian's reports over time within and between the different tracks could also be partly responsible for the differences in risks observed in this study. In most years of the study, where data were available for all three racetracks the risk of MSI was significantly different between racecourses. We cannot discount the possibility that these differences are due to the differences in efficiency of recording at different racetracks, and the likelihood that there would have been changes in veterinary personnel at the courses over the study period.

Causes and types of MSI are described differently between racetracks and throughout the study period. This is probably the result of different criteria and/or experience of official veterinarians working at the racetracks. This could also partly explain the differences in risk factors observed.

Necropsies are not regulated in South America so post mortem information is variable between racecourses. More accurate information about injuries and pre-existing subclinical lesions could help improve this investigation.

2.6 Conclusion

This work has identified some novel risk factors for MSI in racing in South America. Importantly it has highlighted the importance of not only conducting '(inter)national' analyses from as many tracks as possible but also the value of individual track analyses where there are sufficient data to provide adequate statistical power. This study is the first to clearly demonstrate an association between racing having been administered phenylbutazone and the risk of MSI. The next challenge is to attempt to turn this information into policy or regulatory change in the racing jurisdictions in which such practices are permitted.

3 Fatalities

3.1 Introduction

3.1.1 Fatalities in racing

Discovering risk factors for fatalities in thoroughbred racing is essential to assess and design interventions to minimise such events. Working towards equine welfare increases the need of racing industries to measure the risk of horse death during racing.

Racehorses risk for fatalities varies significantly within and between countries and regions. Many North American, British and Australian studies have studied this risk of fatality in horseracing (Peloso, et al., 1994; McKnee, 1995; Estberg, et al., 1996b; Boden, et al., 2010; Boden, et al., 2007). This suggests that characteristics of certain regions or tracks might increase or decrease fatality risk.

3.1.2 Risk factors for fatalities

Even though many risk factors for racehorse death have been identified in Thoroughbred flat racing throughout the years, to the best of the author's knowledge, no previous study has been published that identifies risk factors for fatalities in horse racing in Latin America.

Risk factors for different outcomes that lead to the horse's death have been identified in different regions. In USA risk for fatal MSI (Estberg, et al., 1995; Estberg, et al., 1996b; Estberg, et al., 1996a; Estberg, et al., 1998a; Estberg, et al., 1998b; Carrier, et al., 1998). In the UK outcomes which include fatal fractures (Parkin, et al., 2004b; Parkin, et al., 2005; Parkin, et al., 2006b) fatal injuries (Henley, et al., 2006) and sudden death (Lyle, et al., 2012). In Australia, risk factors for fatalities including fatal injuries and sudden death have also been studied (Boden, et al., 2010; Boden, et al., 2007).

It is very important to conduct studies with local information and local horseracing industry characteristics to determine risk factors that are specific for the region, since it has been suggested that risk factors are likely to differ within and between countries.

This study is focused on describing the prevalence of fatalities at four different racecourses under OSAF jurisdiction and identifying risk factors amongst them.

3.2 Materials and methods. Risk Factor Analysis

3.2.1 Available data

Identified cases of fatality in this study include events that result in the horse death. All fatalities were confirmed as such by racecourse veterinarians working at the racetrack from which data were received. Horses that died or required euthanasia on the same day of the race or, in some cases, the day after (due to injury incurred during the race), were eligible for inclusion in the study. These horses suffered from fatal MSI or sudden death.

Data shown in this chapter belong to four different OSAF racecourses of three different countries. These are racecourses “A”, “B”, “C” and “D”. Racecourses B and C belong to the same Latin American country.

3.2.2 Descriptive analysis

The overall risk of fatality and the risk by year and track were calculated using the method described by Wilson (1927) to calculate 95% confidence intervals around point estimates. All measures of risk were calculated as the number of events per 1000 starts. Simple chi squared tests were used to identify statistically significant differences in the risk of fatality in different years or on different racetracks.

3.2.3 Risk Factor Analysis

The analysis is based on data provided by four from the 14 official racecourses from OSAF jurisdiction. The data includes information on racing fatalities and starts of Thoroughbred horses running on racetracks “A”, “B”, “C” and “D” during an 11, 10, six and five-year period, respectively. A further analysis was also conducted which combined the data from racecourse “B” and “C”, in order to improve statistical power, since they belong to the same country.

Race start data was recorded using a computer system database at each racecourse, and fatality reports were provided on paper by official veterinarians at the racetracks.

In order to validate these studies it has been necessary to check the accuracy of veterinarians reports by confirming their criteria and validating information contained in the reports against information contained in the database. All horses identified as scratched in the race starts data were removed from the starts file.

The studies were conducted with the outcome of interest being measured at the level of a start (a “start” being a horse starting a race).

The retrospective study involved 57 case starts (that resulted in fatality) and 112,131 control starts for racecourse “A”, 127 case starts and 181,197 control starts for racecourse “B”, 59 case starts and 101,810 control starts for racecourse “C” and 49 case starts and 77,008 control starts for racecourse “D”.

3.2.3.1 Selection of cases and controls

A case start was defined as a start in a race, subsequent to which the horse died or was euthanized, at any of the four racecourses. Control starts were defined as any start in a race, which did not end in the horse death or euthanasia, at any of the four racecourses.

3.2.3.2 Risk factors

A total of 18 variables were available for analysis from data collected relating to Racecourse “A” (seven categorical and 11 continuous), 27 for Racecourse “B” (11 categorical and 16 continuous), 25 for Racecourse “C” (11 categorical and 14 continuous), 21 for Racecourse “D” (nine categorical and 12 continuous). A further combined analysis was also conducted combining Racecourses “B” and “C” to improve statistical power, since they belong to the same country. For the analysis of Racecourses “B + C” a total of 23 variables were available for analysis (eight categorical and 15 continuous).

3.2.3.3 Power of the study

All models had at least 80% power to identify odds ratio of 1.5 or more, with 95% confidence, when the prevalence of exposure in the control population was between 10% and 80%.

3.2.3.4 Statistical Method

Every variable was studied and screened independently for each racecourse. Continuous variables were also categorized in order to facilitate the review of the distribution. Akaike Information Criterion (AIC) was calculated for continuous variables and their categorized version in order to asses in which form they would improve the final model. Those that had a lower AIC were taken forward for the multivariable model along with every categorical variable. Unless otherwise indicated by a significant improved AIC for categorical versions of continuous variables, a linear relationship between each continuous variable and the likelihood of fatality was assumed. Details of these variables and results for each Racecourse are shown in section 3.3.4.1 Risk Factor Analysis, Univariable results.

Multivariable logistic regression models were developed for each (combination of) track(s) in order to identify multiple risk factors for fatalities. All variables were included in an automated stepwise logistic regression selection process to adjust for potential confounding resulting in the development of five final multivariable logistic regression models. Different models were produced for Racecourses “A”, “B”, “C”, “D” and “B+C”.

The potential effect of horse in the data analyses was evaluated by creating a mixed-effects model that included horse as a random effect (Reardon, 2013; Boden, et al., 2007; Lyle, et al., 2012). Results were nearly identical (less than 10% change in ORs and no meaningful changes in P values) to results obtained with models that did not include random effects so the single level fixed models were retained.

3.3 Results

3.3.1 Fatalities per year

The number and risk of fatalities varied between years. The frequency of fatalities per 1000 starts and number of fatalities that occurred at OSAF’s racecourses for each year are shown in Table 3-1. The risk of fatality ranged from 0.63/1000 starts (2010) to 0.58/1000 starts (2014) with an overall mean risk over the full 11-year period of 0.62/1000 starts (95% CI 0.55-0.69).

Table 3-1: Frequency of fatalities per 1000 starts and number of fatalities per year at participating OSAF racecourses, with 95% CI for frequency estimates and number of racecourses contributing data to each year from 2005 to 2015.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
Starts	9390	25152	25406	26534	26929	60682	63542	61586	63519	62025	47673	472438
Number of Racecourses	1	2	2	2	2	4	4	4	4	4	3	4
Fatalities	5	19	13	21	16	38	35	34	39	36	36	292
per 1000 starts	**0.53**	**0.76**	**0.51**	**0.79**	**0.59**	**0.63**	**0.55**	**0.55**	**0.61**	**0.58**	**0.76**	**0.62**
95% CI	0.23-1.25	0.48-1.18	0.30-0.88	0.52-1.21	0.37-0.97	0.46-0.86	0.40-0.77	0.40-0.77	0.45-0.84	0.42-0.80	0.55-1.05	0.55-0.69

3.3.2 Fatalities per racecourse

The number of fatalities varied between years and racecourse. In all cases, with the exception of racecourse D in 2010 fatality rates are below 1. The risk of fatalities per 1000 starts and number of fatalities that occurred at each racecourse for each year are shown in Table 3-2, and represented graphically in Figure 3-1.

Table 3-2: Frequency of fatalities per 1000 starts and number of fatalities each year, subdivided between the different racecourses, with the 95% CI.

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
A	Starts	9390	9660	9861	9511	9545	9963	11076	10690	11370	10569	10553	112188
	Fatalities	5	10	5	5	2	6	5	5	2	4	8	57
	per 1000 starts	**0.53**	**1.04**	**0.51**	**0.53**	**0.21**	**0.60**	**0.45**	**0.47**	**0.18**	**0.38**	**0.76**	**0.51**
	95% CI	0.23-1.25	0.56-1.90	0.22-1.19	0.22-1.23	0.06-0.76	0.28-1.31	0.19-1.06	0.20-1.09	0.05-0.64	0.15-0.97	0.38-1.50	0.39-0.66
B	Starts		15492	15545	17023	17384	18340	19967	19009	18604	18843	21117	181324
	Fatalities		9	8	16	14	7	11	14	15	13	20	127
	per 1000 starts		**0.58**	**0.51**	**0.94**	**0.81**	**0.38**	**0.55**	**0.74**	**0.81**	**0.69**	**0.95**	**0.70**
	95% CI		0.31-1.10	0.26-1.02	0.58-1.53	0.48-1.35	0.18-0.79	0.31-0.99	0.44-1.24	0.49-1.33	0.40-1.18	0.61-1.46	0.59-0.83
C	Starts						16782	17327	16055	17753	17949	16003	101869
	Fatalities						9	11	7	18	6	8	59
	per 1000 starts						**0.54**	**0.63**	**0.44**	**1.01**	**0.33**	**0.50**	**0.58**
	95% CI						0.28-1.02	0.35-1.14	0.21-0.90	0.64-1.60	0.15-0.73	0.25-0.99	0.45-0.75
D	Starts						15597	15172	15832	15792	14664		77057
	Fatalities						16	8	8	4	13		49
	per 1000 starts						**1.03**	**0.53**	**0.51**	**0.25**	**0.89**		**0.64**
	95% CI						0.63-1.67	0.27-1.04	0.26-1.00	0.10-0.65	0.52-1.52		0.48-0.84

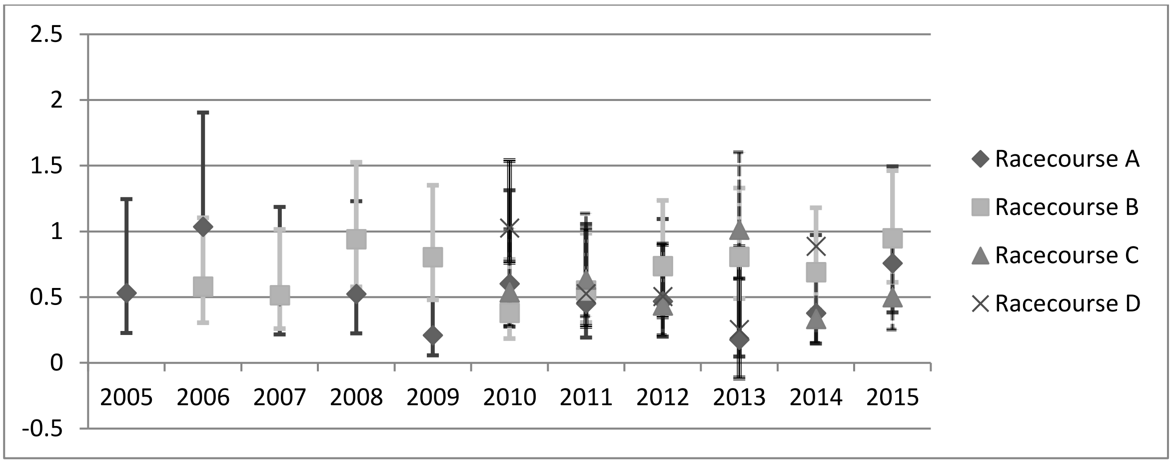

Figure 3-1: Figure showing the frequency of fatalities per 1000 starts each year for the three different OSAF racecourses. (With error bars indication 95% CI)

3.3.3 Causes of fatalities

Fatalities in this were recorded as fatal MSI (fatal fractures and exposed luxations), sudden death and central nervous system trauma. The frequency of these three most common causes of death at four OSAF racecourses included in this study are shown in Figure 3-2 and detailed in Table 3-3. Fatal MSI comprised the majority of fatalities on all four racecourses.

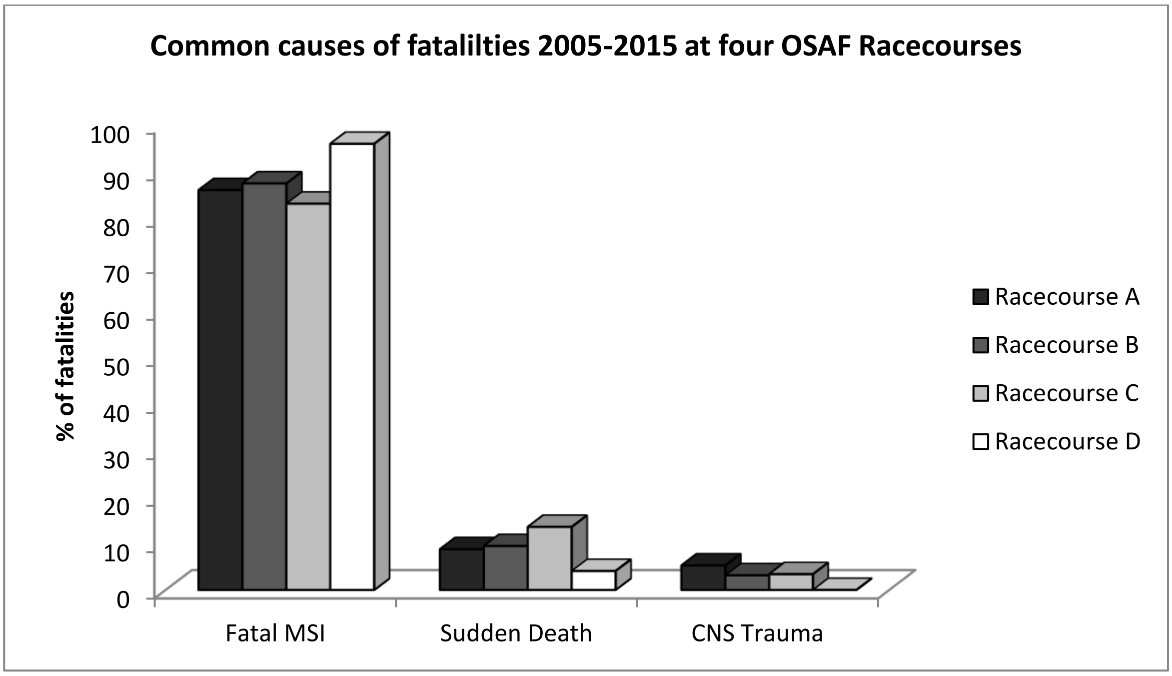

Figure 3-2: Frequency of the different causes of death as percentage cause of total fatalities.

Table 3-3: The risk of each major category of fatalities on each racecourse during study period, with the 95% CI.

	A	B	C	D	A+B+C+D
Period	2005-2015	2006-2015	2010-2015	2010-2014	2005-2015
Starts	112188	181324	101869	77057	472438
Fatalities **per 1000 starts**	57 **0.51**	127 **0.70**	59 **0.58**	49 **0.64**	292 **0.62**
95% CI	0.39-0.66	0.59-0.83	0.45-0.75	0.48-0.84	0.55-0.69
Fatal MSI **per 1000 starts**	49 **0.44**	111 **0.61**	49 **0.48**	47 **0.61**	256 **0.54**
95% CI	0.33-0.58	0.51-0.74	0.36-0.64	0.46-0.81	0.48-0.61
Sudden Death **per 1000 starts**	5 **0.04**	12 **0.07**	8 **0.08**	2 **0.03**	27 **0.06**
95% CI	0.02-0.10	0.04-0.12	0.04-0.15	0.01-0.09	0.04-0.08
CNS Trauma **per 1000 starts**	3 **0.03**	4 **0.02**	2 **0.02**	0 **0.00**	9 **0.02**
95% CI	0.01-0.08	0.01-0.06	0.01-0.07	0.00-0.05	0.01-0.04

3.3.4 Risk factor analysis

3.3.4.1 Univariable results

Tables showing univariable analysis for categorical and continuous variables for the participating racecourses are shown in Tables 3-4, 3-5, 3-7, 3-8, 3-11, 3-12, 3-15, 3-16, 3-19 and 3-20. AIC values for numerical variables as continuous or as categorical forms are shown in Tables 3-6, 3-9, 3-13 and 3-17, along with details of each continuous variable included in the model in its categorical form in Tables 3-10, 3-14, 3-18, and 3-22. Results are described for each racecourse model and differences between them are highlighted.

3.3.4.1 Racecourse “A”

Univariable analysis for Racecourse “A” comprised seven categorical variables (first start at the racecourse, the first year of the horse’s career, gender, authorized medication, previous injuries at the racetrack, season of the year and track status) and 11 continuous variables (age, age at first start, distance, cumulative distance, field size, horse weight, layups, layup days, starts between 0 and 90 days since the date of the fatality, starts between 90 and 180 days since the date of the fatality, total amount of starts). None of the continuous variables had lower AIC in a categorical form.

Table 3-4. Univariable analysis for categorical variables. Racecourse "A"

Variable	Total n=112188	Cases n=57	Controls n=112131	Pr(>|z|)	Odds Ratio	95% CI
GENDER						
Female	40303	14	40289		REF	
Male	71885	43	71842	0.077	1.72	0.94 – 3.15
DECLARED MEDICATION						
FB or FF	72763	39	72724		REF	
FS or None	39425	18	39407	0.573	0.85	0.49 – 1.49
TRACK STATUS						
Good	91545	43	91502		REF	
Muddy	7526	4	7522	0.813	1.13	0.41 – 3.15
Wet	6498	4	6494	0.605	1.31	0.47 – 3.65
Heavy	6619	6	6613	0.131	1.93	0.82 – 4.54
FIRST YEAR OF CAREER						
No	53199	28	53171		REF	
Yes	58989	29	58960	0.797	0.93	0.56 – 1.57
FIRST START						
No	103101	53	103048		REF	
Yes	9087	4	9083	0.765	0.86	0.31 – 2.37
PREVIOUS INJURIES						
No	112169	57	112112		REF	
Yes	19	0	19	0.987	0.00	0.00 – 0.00
YEAR SEASON						
Autumn	23544	14	23530		REF	
Spring	22907	10	22897	0.455	0.73	0.33 – 1.65
Summer	41613	21	41592	0.634	0.85	0.43 – 1.67
Winter	24124	12	24112	0.650	0.84	0.39 – 1.81

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 3-5: Univariable analysis for continuous variables. Racecourse “A”

Variable	Pr(>|z|)	Odds Ratio	95% CI		
DISTANCE					
Per extra 100 meter	0.045	1.09	1.00	–	1.19
AGE					
Per extra year	0.867	0.98	0.79	–	1.22
WEIGHT					
Per extra 10 kg	0.338	1.04	0.96	–	1.12
STARTS 0 to 90 days					
Per extra start	0.344	1.07	0.93	–	1.24
STARTS 90 to 180					
Per extra start	0.221	1.09	0.95	–	1.24
TOTAL STARTS					
Per extra start	0.569	1.01	0.98	–	1.03
AGE AT FIRST START					
Per extra year	0.718	0.94	0.67	–	1.31
FIELD SIZE					
Per extra competitor	0.032	1.13	1.01	–	1.27
CUMULATIVE DISTANCE					
Per extra 1000 meters	0.580	1.01	0.99	–	1.02
LAYUPS					
Per extra layup	0.451	0.93	0.77	–	1.12
LAYUP DAYS					
Per extra day	0.513	1.00	1.00	–	1.00

Table 3-6: Comparative AIC values. Racecourse "A"

VARIABLE	AIC as continuous	AIC as categorical
AGE	982.6191	986.4045
AGE AT FIRST START	982.5147	982.5658
CUMULATIVE DISTANCE	982.352	987.7929
DISTANCE	979.1044	985.8461
FIELD SIZE	977.9599	984.3194
HORSE WEIGHT	981.6735	982.9965
LAYUP DAYS	982.0516	984.2541
LAYUPS	982.0516	983.4157
STARTS 0-90 DAYS	981.7736	987.2911
STARTS 90-180 DAYS	981.2082	983.3658
STARTS CAREER	982.3345	986.6127

3.3.4.2 Racecourse “B”

Univariable analysis for Racecourse “B” comprised 11 categorical variables (time of day, first start at the racecourse, the first year of the horse’s career, gender, authorized medication, previous injuries at the racetrack, race type, season of the year, racing surface, track configuration and track status) and 16 continuous variables (age, age at first start, distance, cumulative distance, field size, horse weight, layups, layup days, scratches, speed, dividend, starts between 0 and 90 days before the date of the fatality, starts between 90 and 180 days before the date of the fatality, total amount of starts, jockey weight, jockey race weight). Jockey weight, jockey race weight, and starts between 0 and 90 days before the date of the current race were retained for further modelling as categorical variables.

Table 3-7: Univariable analysis for categorical variables. Racecourse “B”

Variable	Total n=181324	Cases n=127	Controls n=181197	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Female	77171	46	77125		REF			
Male	104153	81	104072	0.149	1.30	0.91	–	1.87
AUTHORIZED MEDICATION								
FB or FF	126234	108	126126		REF			
FS or None	55090	19	55071	<0.001	0.40	0.25	–	0.66
FIRST START								
No	148853	109	148744		REF			
Yes	32471	18	32453	0.274	0.76	0.46	–	1.25
PREVIOUS INJURIES								
No	181205	127	181078		REF			
Yes	119	0	119	0.977	0.00	0.00	–	0.00
YEAR SEASON								
Autumn	47829	34	47795		REF			
Spring	46036	31	46005	0.827	0.95	0.58	–	1.54
Summer	41796	23	41773	0.343	0.77	0.46	–	1.31
Winter	45663	39	45624	0.434	1.20	0.76	–	1.90
SURFACE								
Dirt	104228	86	104142		REF			
Turf	77096	41	77055	0.021	0.64	0.44	–	0.93
TIME OF DAY								
After 6 pm	101356	76	101280		REF			
Before 6 pm	79968	51	79917	0.371	0.85	0.60	–	1.21
RACE TYPE								
Group	4977	0	4977		REF			
Listed & Non Grade	3050	1	3049	0.960	279288.34	0.00	–	0.00
Other	173297	126	173171	0.958	621567.63	0.00	–	0.00
TRACK STATUS								
Wet	17389	12	17377		REF			
Normal	146906	105	146801	0.908	1.04	0.57	–	1.88
Heavy	17029	10	17019	0.706	0.85	0.37	–	1.97
FIRST YEAR OF CAREER								
No	95082	74	95008		REF			
Yes	86242	53	86189	0.189	0.79	0.55	–	1.12
TRACK CONFIGURATION								
Diagonal	22515	11	22504		REF			
Straight	84157	56	84101	0.349	1.36	0.71	–	2.60
Turn	74652	60	74592	0.129	1.65	0.87	–	3.13

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 3-8: Univariable analysis for continuous variables. Racecourse "B"

Variable	Pr(>|z|)	Odds Ratio	95% CI
AGE			
Per extra year	0.026	1.18	1.02 – 1.36
JOCKEY RACE WEIGHT			
Per extra Kg	0.246	1.09	0.94 – 1.26
HORSE WEIGHT			
Per extra 10 Kg	0.107	1.04	0.99 – 1.10
DIVIDENDS			
Per extra 10 units	0.934	1.00	0.97 – 1.03
SCRATCHES			
Per extra scratch	0.050	1.21	1.00 – 1.46
DISTANCE			
Per extra 100 meter	0.549	1.02	0.96 – 1.09
TOTAL STARTS			
Per extra start	0.330	1.01	0.99 – 1.04
STARTS 0 to 90 days			
Per extra start	0.924	0.99	0.86 – 1.14
STARTS 90 to 180 days			
Per extra start	0.202	1.09	0.96 – 1.23
AGE AT FIRST START			
Per extra year	0.040	1.25	1.01 – 1.54
FIELD SIZE			
Per extra competitor	0.034	1.07	1.01 – 1.14
CUMULATIVE DISTANCE			
Per extra meter	0.462	1.01	0.99 – 1.03
LAYUPS			
Per extra layup	0.315	1.06	0.95 – 1.18
SPEED			
Per extra k/h	0.474	1.01	0.99 – 1.03
LAYUP DAYS			
Per extra 15 days	0.117	1.01	1.00 – 1.02
JOCKEY WEIGHT			
Per extra Kg	0.134	1.08	0.98 – 1.18

Table 3-9: Comparative AIC values. Racecourse "B"

VARIABLE	AIC as continuous	AIC as categorical
AGE	2098.116	2098.909
AGE AT FIRST START	2098.889	2098.313
JOCKEY WEIGHT	2100.451	2097.637
CUMULATIVE DISTANCE	2102.408	2103.781
DISTANCE	2102.571	2107.101
DIVIDEND	2102.914	2103.425
FIELD SIZE	2098.439	2098.909
HORSE WEIGHT	2100.352	2103.422
JOCKEY RACE WEIGHT	2101.568	2095.945
LAYUP DAYS	2100.633	2103.09
LAYUPS	2101.951	2103.143
SCRATCHES	2099.568	2100.887
SPEED	2102.429	2106.623
STARTS 0-90 DAYS	2102.912	2101.953
STARTS 90-180 DAYS	2101.371	2101.604
STARTS CAREER	2102.027	2105.263

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 3-10: Categorised continuous variables for the final model. Racecourse "B".

Variable	Total n=181324	Cases n=127	Controls n=181197	Pr(>|z|)	Odds Ratio	95% CI
JOCKEY WEIGHT						
Less than 57 Kg.	105474	61	105413	0.021	0.66	0.47 – 0.94
57 Kg or more	75850	66	75784		REF	
JOCKEY RACE WEIGHT						
Less than 57 Kg	77805	40	77765	0.010	0.61	0.42 – 0.89
57 kg or more	103519	87	103432		REF	
STARTS 0-90 DAYS						
No starts	64949	42	64907		REF	
1 & 2	85926	69	85857	0.268	1.24	0.85 – 1.82
3 and more	30449	16	30433	0.480	0.81	0.46 – 1.45

3.3.4.3 Racecourse "C"

Univariable analysis for Racecourse "C" comprised 10 categorical variables (time of day, gender, authorized medication, previous injuries at the racetrack, race type, season of the year, racing surface, track, track configuration and track status) and 14 continuous variables (age, distance, cumulative distance, field size, horse weight, layups, layup days, scratches, speed, starts between 0 and 90 days before the date of the fatality, starts between 90 and 180 days before the date of the fatality, total amount of starts, jockey weight, jockey race weight). Jockey weight, jockey race weight, layup days and layups were retained for further modelling as categorical variables.

Table 3-11: Univariable analysis for categorical variables. Racecourse "C"

Variable	Total n=101869	Cases n=59	Controls n=101810	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Female	38979	14	38965		REF			
Male	62890	45	62845	0.024	1.99	1.09	–	3.63
AUTHORIZED MEDICATION								
FB or Both	67516	37	67479		REF			
FS or None	34353	22	34331	0.563	1.17	0.69	–	1.98
FIRST STARTS								
No	79205	46	79159		REF			
Yes	22664	13	22651	0.968	0.99	0.53	–	1.83
PREVIOUS INJURIES								
No	101667	58	101609		REF			
Yes	202	1	201	0.032	8.72	1.20	–	63.23
YEAR SEASON								
Autumn	26557	16	26541		REF			
Spring	25461	21	25440	0.344	1.37	0.71	–	2.62
Summer	22655	8	22647	0.217	0.59	0.25	–	1.37
Winter	27196	14	27182	0.667	0.85	0.42	–	1.75
TRACK								
Dirt with turn	57935	36	57899		REF			
Dirt straight	39832	22	39810	0.663	0.89	0.52	–	1.51
Turf with turn	4102	1	4101	0.355	0.39	0.05	–	2.86
TRACK CONFIGURATION								
Straight	39832	22	39810		REF			
Turn	62037	37	62000	0.775	1.08	0.64	–	1.83
SURFACE								
Dirt	97767	58	97709		REF			
Turf	4102	1	4101	0.377	0.41	0.06	–	2.96
TIME OF DAY								
After 6	53657	30	53627		REF			
Before 6	48212	29	48183	0.779	1.08	0.65	–	1.79
TRACK STATUS								
Muddy	1086	2	1084		REF			
Wet	8595	7	8588	0.309	0.44	0.09	–	2.13
Normal	81552	43	81509	0.084	0.29	0.07	–	1.18
Heavy	10636	7	10629	0.199	0.36	0.07	–	1.72
RACE TYPE								
Other	97650	53	97597		REF			
Group graded	3134	5	3129	0.021	2.94	1.18	–	7.37
Listed & Non graded	1085	1	1084	0.600	1.70	0.23	–	12.30

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 3-12: Univariable analysis for continuous variables. Racecourse "C"

Variable	Pr(>|z|)	Odds Ratio	95% CI
AGE			
Per extra year	0.405	1.09	0.88 – 1.36
HORSE WEIGHT			
Per extra 10 Kgs	<0.001	1.15	1.07 – 1.24
JOCKEY WEIGHT			
Per extra Kg	0.985	1.00	0.87 – 1.15
SCRATCHES			
Per extra scratch	0.237	0.72	0.42 – 1.24
DISTANCE			
Per extra 100 meters	0.269	1.05	0.96 – 1.15
TOTAL STARTS			
Per extra start	0.606	0.98	0.93 – 1.04
STARTS 0 to 90 days			
Per extra start	0.581	1.06	0.86 – 1.30
STARTS 90 to 180 days			
Per extra start	0.833	1.02	0.82 – 1.28
FIELD SIZE			
Per extra competitor	0.426	1.04	0.95 – 1.14
CUMULATIVE DIST			
Per extra meter	0.136	1.10	0.97 – 1.25
LAYUPS			
Per extra layup	0.669	1.04	0.87 – 1.25
SPEED			
Per extra Km/h	0.664	0.90	0.57 – 1.44
LAYUP DAYS			
Per extra 10 days	0.644	1.00	0.99 – 1.01
JOCKEY RACE WEIGHT			
Per extra Kg	0.645	0.96	0.79 – 1.16

Table 3.13: Comparative AIC values. Racecourse "C"

VARIABLE	AIC as continuous	AIC as categorical
AGE	1000.845	1003.981
JOCKEY WEIGHT	1001.525	1001.209
CUMULATIVE DISTANCE	1001.427	1006.591
DISTANCE	1000.375	1002.012
FIELD SIZE	1000.896	1004.864
HORSE WEIGHT	988.1272	991.2885
JOCKEY RACE WEIGHT	1001.318	1000.375
LAYUP DAYS	1001.32	1001.144
LAYUPS	1001.349	1000.77
SCRATCHES	999.8734	1000.706
SPEED	1001.338	1007.286
STARTS 0-90 DAYS	1001.23	1001.447
STARTS 90-180 DAYS	1001.483	1003.106
STARTS CAREER	1001.245	1004.845

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 3-14: Categorised continuous variables for the final model. Racecourse "C".

Variable	Total n=101869	Cases n=59	Controls n=101810	Pr(>|z|)	Odds Ratio	95% CI
JOCKEY WEIGHT						
Less than 57 Kg	61985	38	61947	0.576	1.16	0.68 – 1.98
57 kg or more	39884	21	39863	REF	1.00	
JOCKEY RACE WEIGHT						
Less than 57 kg	53353	35	53318	0.287	1.33	0.79 – 2.23
57 kg or more	48516	24	48492	REF	1.00	
LAYUP DAYS						
0	44332	29	44303	REF	1.00	
60 to 383	37211	16	37195	0.178	0.66	0.36 – 1.21
More than 383	20326	14	20312	0.874	1.05	0.56 – 1.99
LAYUPS						
None	44332	29	44303	REF	1.00	
1 or 2	57537	30	57507	0.384	0.80	0.48 – 1.33

3.3.4.4 Racecourse "D"

Univariable analysis for Racecourse "D" comprised nine categorical variables (time of day, first start, first year of career, gender, medication, race type, year season, racing surface and jockey experience) and 12 continuous variables (age, distance, cumulative distance, field size, horse weight, layups, layup days, starts between 0 and 90 days before the date of the fatality, starts between 90 and 180 days before the date of the fatality, total amount of starts, jockey weight, jockey race weight). Cumulative distance, horse weight, jockey weight, layup days and starts between 90 and 180 days before the date of the fatality were retained for further modelling as categorical variables.

Table 3-15: Univariable analysis for categorical variables. Racecourse "D"

Variable	Total n=77057	Cases n=49	Controls n=77008	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Female	16	16		REF				
Male	46057	33	46024	1.388	1.39	0.76	–	2.52
AUTHORIZED MEDICATION								
None	60136	43	60093	REF				
FS	15420	6	15414	0.544	0.54	0.23	–	1.28
FS (1)	1448	0	1448	<0.001	0.00	0.00	_	0.00
FS (2)	53	0	53	<0.001	0.00	0.00	_	0.00
FIRST START								
No	69727	41	69686	REF				
yes	7330	8	7322	1.857	1.86	0.87	–	3.96
SURFACE								
Dirt	45065	28	45037	REF				
Turf	31992	21	31971	1.057	1.06	0.60	–	1.86
JOCKEY EXPERIENCE								
Learner	18486	16	18470	REF				
Professional	58571	33	58538	0.651	0.65	0.36	–	1.18
YEAR SEASON								
Autumn	19358	11	19347	REF				
Spring	19775	12	19763	1.068	1.07	0.47	–	2.42
Summer	17147	16	17131	1.643	1.64	0.76	–	3.54
Winter	20777	10	20767	0.847	0.85	0.36	–	1.99
FIRST YEAR CAREER								
No	47694	30	47664	REF				
Yes	29363	19	29344	1.029	1.03	0.58	–	1.83
RACE TYPE								
	51127	33	51094	REF				
Other	25930	16	25914	0.956	0.96	0.52	–	1.73
TIME OF DAY								
After 6	48479	30	48449	REF				
Before 6	28578	19	28559	1.074	1.07	0.60	–	1.90

FS= furosemide, FS(1)=furosemide for the first time, FS(2)= furosemide for the second time.

Table 3-16: Univariable analysis for continuous variables. Racecourse "D"

Variable	Pr(>|z|)	Odds Ratio	95% CI
DISTANCE			
Per extra 100 meters	0.036	1.09	1.01 – 1.18
AGE			
Per extra year	0.613	0.94	0.74 – 1.19
JOCKEY WEIGHT			
Per extra kg	0.042	1.11	1.00 – 1.23
CARRIED WEIGHT			
Per extra kg	0.710	1.02	0.90 – 1.59
HORSE WEIGHT			
Per extra 10 kgs	0.295	1.02	0.98 – 1.06
TOTAL STARTS			
Per extra start	0.121	0.97	0.93 – 1.01
STARTS 0 to 90 days			
Per extra start	0.118	0.86	0.70 – 1.04
STARTS 90 to 180 days			
Per extra start	0.256	0.90	0.76 – 1.08
FIELD SIZE			
Per extra competitor	0.509	0.96	0.83 – 1.09
CUMULATIVE DISTANCE			
Per extra 500 meters	0.152	0.99	0.98 – 1.00
LAYUPS			
Per extra layup	0.788	0.97	0.76 – 1.23
LAYUP DAYS			
Per extra 10 days	0.773	1.00	0.98 – 1.02

Table 3-17: Compared AIC values. Racecourse "D"

VARIABLE	AIC as continuous	AIC as categorical
AGE	823.0366	826.1443
CARRIED WEIGHT	823.167	823.2723
CUMULATIVE DISTANCE	820.9417	817.8277
DISTANCE	819.5506	824.9633
FIELD SIZE	822.8498	826.0332
HORSE WEIGHT	822.4367	816.4952
JOCKEY WEIGHT	820.4218	819.5506
LAYUP DAYS	823.2102	822.309
LAYUPS	823.222	823.5469
STARTS 0-90 DAYS	820.7583	824.0446
STARTS 90-180 DAYS	821.9459	821.304
STARTS CAREER	820.5043	820.591

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 3-18: Categorised continuous variables for the final model. Racecourse "D".

Variable	Total n=77057	Cases n=49	Controls n=77008	Pr(>|z|)	Odds Ratio	95% CI
CUMULATIVE DISTANCE						
≤3600	15829	16	15813	0.765	1.12	0.54 – 2.29
3600> to ≤7400	15155	3	15152	0.017	0.22	0.06 – 0.76
7400> to ≤13000	15448	14	15434		REF	
13000> to ≤22300	15341	8	15333	0.212	0.58	0.24 – 1.37
>22300	15284	8	15276	0.215	0.58	0.24 – 1.38
HORSE WEIGHT						
435≥ to ≤490	62498	32	62466		REF	
>490	14559	17	14542	0.006	2.28	1.27 – 4.11
JOCKEY WEIGHT						
Less than 57 Kg	33743	15	33728	0.067	0.57	0.31 – 1.04
57 kg or more	43314	34	43280		REF	
LAYUP DAYS						
0	37800	29	37771		REF	
60 to 211 days	23888	10	23878	0.098	0.55	0.27 – 1.12
More than 211	15369	10	15359	0.653	0.85	0.41 – 1.74
STARTS 90 to 180 days						
No starts	26476	22	26454		REF	
1 or 2	24982	10	24972	0.055	0.48	0.23 – 1.02
3 or more	25599	17	25582	0.487	0.80	0.42 – 1.50

3.3.4.5 Racecourse “B + C”

A model was built combining data from racecourses B and C in order to improve statistical power. These racecourses where chosen to be combined since they belong to the same country in OSAF jurisdiction. New risk factors for the country could be found by combining information from these two important racecourses. Univariable analysis for Racecourses “B+C” comprised eight categorical variables (time of day, first start at one of the racecourses, gender, authorized medication, previous injuries, season of the year, surface and track configuration) and 15 continuous variables (age, distance, cumulative distance, field size, horse weight, layups, layup days, speed, starts between 0 and 30 days before the date of the fatality, starts between 30 and 60 days before the date of the fatality, starts between 60 and 90 days before the date of the fatality, starts between 90 and 180 days before the date of the fatality, total amount of starts, jockey weight, jockey race weight). Jockey weight, jockey race weight, starts between 0 and 30 days before the date of the fatality, starts between 30 and 60 days before the date of the fatality and starts between 90 and 180 days before the date of the fatality were retained for further modelling as categorical variables.

Table 3-19: Univariable analysis for categorical variables. Racecourses "B+C"

Variable	Total n=283193	Cases n=186	Controls n=283007	Pr(>|z|)	Odds Ratio	95% CI		
GENDER								
Male	167043	126	166917		REF			
Female	116150	60	116090	0.016	0.68	0.50	–	0.93
AUTHORIZED MEDICATION								
FB or Both (FF)	193750	145	193605		REF			
FS or None	89443	41	89402	0.006	0.61	0.43		0.87
FIRST START								
No	244885	159	244726		REF			
Yes (at one of the 2)	38308	27	38281	0.693	1.09	0.72	–	1.63
PREVIOUS INJURIES								
No	282624	185	282439		REF			
Yes	569	1	568	0.325	2.69	0.38	–	19.22
YEAR SEASON								
Autumn	74386	50	74336		REF			
Spring	71497	52	71445	0.691	1.08	0.73	–	1.60
Summer	64451	31	64420	0.143	0.72	0.46	–	1.12
Winter	72859	53	72806	0.688	1.08	0.74	–	1.59
SURFACE								
Dirt	201995	144	201851		REF			
Turf	81198	42	81156	0.067	0.73	0.51	–	1.02
TRACK CONFIGURATION								
Straight	123989	78	123911		REF			
Diagonal (SI)	22515	11	22504	0.432	0.78	0.41	–	1.46
Turn	136689	97	136592	0.428	1.13	0.84	–	1.52
TIME OF DAY	283193							
After 6	155013	106	154907		REF			
Before 6	128180	80	128100	0.537	0.91	0.68	–	1.22

FB = phenylbutazone, FS = furosemide, FF = indicates races in which both FB and FS are permitted.

Table 3-20: Univariable analysis for continuous variables. Racecourses "B+C"

Variable	Pr(>|z|)	Odds Ratio	95% CI		
DISTANCE					
Per extra 100 meters	0.203	1.03	0.98	–	1.09
AGE					
Per extra year	0.021	1.15	1.02	–	1.30
HORSE WEIGHT					
Per extra 10 Kgs	0.001	1.07	1.03	–	1.12
STARTS CAREER					
Per extra start	0.946	1.00	0.98	–	1.02
FIELD SIZE					
Per extra horse	0.021	1.06	1.01	–	1.12
CUMULATIVE DISTANCE					
Per extra 1000 meter	0.867	1.00	0.98	–	1.01
LAYUPS					
Per extra layup	0.715	1.02	0.93	–	1.12
LAYUP DAYS					
Per extra 15 days	0.413	1.00	1.00	–	1.01
SPEED					
Per extra km/h	0.573	1.00	0.98	–	1.01
STARTS 0-30 days					
Per extra starts	0.686	1.05	0.83	–	1.32
STARTS 30-60 days					
Per extra start	0.562	1.06	0.87	–	1.30
STARTS 60-90 days					
Per extra start	0.654	0.95	0.77	–	1.18
STARTS 90-180 days					
Per extra start	0.783	1.01	0.92	–	1.12
JOCKEY RACE WEIGHT					
Per extra Kg	0.434	1.05	0.93	–	1.17
JOCKEY WEIGHT					
Per extra Kg	0.256	1.05	0.97	–	1.14

Table 3-21: Compared AIC values. Racecourse “B+C”

Variables	AIC as continuous	AIC as categorical
AGE	3096.756	3100.542
CUMULATIVE DISTANCE	3101.917	3105.806
DISTANCE	3100.383	3100.975
FIELD SIZE	3096.628	3098.805
HORSE WEIGHT	3091.127	3092.22
JOCKEY WEIGHT	3100.313	3099.369
JOCKEY RACE WEIGHT	3101.328	3099.235
LAYUP DAYS	3101.293	3102.797
LAYUPS	3101.813	3101.968
SPEED	3101.625	3106.295
STARTS 0-30 DAYS	3101.783	3101.609
STARTS 30-60 DAYS	3101.613	3100.679
STARTS 60-90 DAYS	3101.741	3101.769
STARTS 90-180 DAYS	3101.87	3101.861
STARTS CAREER	3101.94	3103.67

Grey boxes indicate lower AIC as categorical, therefore included in the model as such.

Table 3-22: Categorised continuous variables for the final model. Racecourses “B+C”.

Variable	Total 283193	Cases n=186	Controls n=283007	Pr(>|z|)	Odds Ratio	95% CI
JOCKEY WEIGHT						
Less than 57 Kg	167212	99	167113	0.107	0.79	0.59 – 1.05
57 kg or more	115981	87	115894		REF	
JOCKEY RACE WEIGHT						
Less than 57 Kg	131158	75	131083	0.102	0.78	0.58 – 1.05
57 Kg or more	152035	111	151924		REF	
STARTS 0-30 DAYS						
No starts	282390	185	282205		REF	
1	803	1	802	0.522	1.90	0.27 – 13.59
STARTS 30-60 DAYS						
No starts	156282	95	156187		REF	
1 and more	126911	91	126820	0.260	1.18	0.88 – 1.57
STARTS 90 to 180 days						
No starts	138593	93	138500		REF	
1 or more	144600	93	144507	0.772	0.96	0.72 – 1.28

3.3.4.2 Multivariable Analysis

A total of two variables were found to be significantly associated with fatalities at each of Racecourse “A”, “B” and “C”, while five were identified for Racecourse “D” and four for Racecourse “B + C”. Final models are shown in Tables 3-23 to 3-27.

3.3.4.2.1. Racecourse "A"

Variables that were found to be associated with increased odds of fatality in flat racing at Racecourse "A" were: field size and race distance. In larger fields horses had greater odds of fatality (OR 1.14, 95% C.I. 1.02-1.27 per extra competitor). Longer running distances were also associated with increased odds of fatality (OR 1.10, 95% C.I. 1.01-1.20 per extra 100 meters).

One more variable was retained within the model (gender), due to the fact that it resulted in a moderate improvement in the overall fit of the model as measured by AIC. This was gender; males had greater odds of suffering a fatality but this result was not significant at the 95% confidence level.

Table 3-23: Multivariable logistic regression model for fatalities in Racecourse "A"

Variable	Pr(>|z|)	Odds Ratio	95% CI		
FIELD SIZE					
Per extra horse	0.023	1.14	1.02	–	1.27
DISTANCE					
Per extra 100 meters	0.034	1.10	1.01	–	1.20
GENDER					
Female		REF			
Male	0.144	1.57	0.86	–	2.89

3.3.2.2 Racecourse “B”

Variables that were found to be associated with odds of fatality in flat racing in Racecourse “B” were: authorized medication and field size. Horses that were declared to run with no medication at all or only with furosemide (FS or None) had lower odds of fatality than horses running with phenylbutazone or with phenylbutazone and furosemide (FB or FF) (OR 0.41, 95% C.I. 0.25-0.66). Horses running in larger field size had greater odds of suffering a fatality (OR 1.07, 95% C.I. 1.00-1.14 per extra competitor).

Table 3-24: Multivariable logistic regression model for fatalities in Racecourse “B”

Variable	Pr(>|z|)	Odds Ratio	95% CI
AUTHORIZED MEDICATION			
FB or FF		REF	
FS or None	<0.001	0.41	0.25 – 0.66
FIELD SIZE			
Per extra horse	0.041	1.07	1.00 – 1.14

3.3.2.3 Racecourse "C"

Variables that were found to be significantly associated with odds of fatality in flat racing in Racecourse "C" were: horse weight and previous injuries. Heavier horses had increased odds of fatality than lighter horses (OR 1.15, 95% C.I. 1.07-1.24 per extra 10 kilograms). Horses with recorded previous injuries at the racetrack were also at increased risk of fatality (OR 8.18, 95% C.I. 1.12-59.64).

One more variable was retained within the model (scratches), due to the fact that they resulted in a moderate improvement in the overall fit of the model as measured by AIC. Horses with more scratches had greater odds of suffering a fatality but this result was not significant at the 95% confidence level.

Table 3-25: Multivariable logistic regression model for fatalities in Racecourse "C"

Variable	Pr(>|z|)	Odds Ratio	95% CI
HORSE WEIGHT			
Per extra 10 kilograms	<0.001	1.15	1.07 – 1.24
SCRATCHES			
Per extra scratch	0.143	0.66	0.39 – 1.15
PREVIOUS INJURIES			
No		REF	
Yes	0.038	8.18	1.12 – 59.64

3.3.2.4 Racecourse "D"

Variables that were found to be significantly associated with odds of fatality in flat racing in Racecourse "D" were: horse weight, cumulative distance, race distance, jockey weight and jockey experience. Horses over 490 kilograms had greater odds of fatality than horses under 490 kilograms (OR 2.21, 95% C.I. 1.22-3.99). Horses with a cumulative distance (racing history) between 3600 to 7400 meters had smaller odds of fatality compared with horses with cumulative distance between 7400 to 13000 meters (OR 0.24, 95% C.I. 0.07-0.85). Odds of fatality also increased with the race length, longer races were riskier (OR 1.11, 95% C.I. 1.03-1.21). As regards jockeys, horses ridden by jockeys of less than 57 kilograms had less risk of fatality than horses ridden by jockeys over 57 kilograms (OR 0.47, 95% C.I. 0.25-0.89), and professional jockeys also reduced the odds of fatality in horses (OR 0.46, 95% C.I. 0.25-0.86).

Table 3-26: Multivariable logistic regression model for fatalities in Racecourse "D"

Variable	Pr(>|z|)	Odds Ratio	95% CI
HORSE WEIGHT			
<490 Kgs		REF	
>490 Kgs	0.009	2.21	1.22 – 3.99
CUMULATIVE DISTANCE (mts)			
≤3600	0.310	1.46	0.70 – 3.03
3600> to ≤7400	0.026	0.24	0.07 – 0.85
7400> to ≤13000		REF	
13000> to ≤22300	0.151	0.53	0.22 – 1.26
>22300	0.137	0.52	0.22 – 1.23
DISTANCE			
Per extra 100 meters	0.008	1.11	1.03 – 1.21
JOCKEY WEIGHT			
More than 57 Kg		REF	
Less than 57 Kg	0.020	0.47	0.25 – 0.89
JOCKEY EXPERIENCE			
Non professional		REF	
Professional	0.014	0.46	0.25 – 0.86

3.3.2.5 Racecourse "B + C"

Variables that were found to be significantly associated with odds of fatality in flat racing in Racecourse "B + C" were: horse weight, authorized medication, field size and distance. Heavier horses had greater odds of fatality than lighter horses (OR 1.07, 95% C.I. 1.02-1.11 per extra 10 kilograms). As regards medication, horses that were declared to run with no medication at all or only with furosemide (FS or None) had lower odds of fatality than horses running with phenylbutazone (FB) or with phenylbutazone and furosemide (FB or FF) (O.R 0.63, 95% C.I. 0.44-0.91). Horses running in larger fields were more likely to suffer a fatality (OR 1.07, 95% C.I. 1.02-1.13). Longer race distances were also associated with a greater risk for fatality (OR 1.1, 95% C.I. 1.03-1.18 per extra 100 meters).

Other variables were retained within the model (cumulative distance, total amount of starts and running surface), due to the fact that they resulted in a moderate improvement in the overall fit of the model as measured by. These were cumulative distance, total amount of starts and racing surface. These results were not significant at the 95% confidence level.

Table 3-27: Multivariable logistic regression model for fatalities in Racecourse "B+C"

Variable	Pr(>|z|)	Odds Ratio	95% CI
HORSE WEIGHT			
Per extra 10 Kg	0.002	1.07	1.02 - 1.11
AUTHORIZED MEDICATION			
FB or FF		REF	
FS or None	0.015	0.63	0.44 - 0.91
FIELD SIZE			
Per extra horse	0.012	1.07	1.02 - 1.13
DISTANCE			
Per extra 100 meters	0.006	1.1	1.03 - 1.18
CUMULATIVE DISTANCE			
Per extra 1000 meters	0.092	0.92	0.84 - 1.01
TOTAL STARTS			
Per extra starts	0.142	1.09	0.97 - 1.23
SURFACE			
Dirt		REF	
Turf	0.156	0.77	0.54 - 1.10

3.3.4.2.5 Comparative results

Risk factors for fatalities varied between the four OSAF racecourses. Some of them were common and were risk factors at more than one racecourse, whereas others were exclusive to just one of the racecourses. Table 3-28 shows the results for each racecourse, an 'X' indicates that that variable has resulted as a statistically significant risk factor for that racecourse. No single risk factor was common to all four racecourses.

Table 3-28: Comparative results for risk factors at the four OSAF racecourses.

FATALITIES RESULTS					
	RACECOURSE				
VARIABLE	A	B	C	D	B+C
Horse weight			X	X	X
Distance	X			X	X
Field size	X	X			X
Authorized Medication		X			X
Previous injuries			X		
Jockey weight				X	
Jockey Experience				X	
Cumulative Distance Raced				X	

3.4 Discussion

3.4.1 Risk Factors common to models for Racecourses A, D and Racecourses B+C

Distance

Results indicated that in longer races the odds of death were higher. For racecourses "A", "D" and "B+C" models results suggested that for every 100 extra meters the odds of fatality increased. As it was explained for MSI as an outcome this could be due to the fact that the horses in longer races spend more time at risk since they have to cover more ground (Parkin, et al., 2004b). Horses running longer distances are exposed longer time to fatigue of their musculoskeletal structures due to the high-speed exercise. Many studies had also proved that longer racing distances were more risky for suffering fatalities such as fatal fractures (Parkin, et al., 2005), any cause of death, such as euthanasia for humane reasons or sudden death (Boden, et al., 2007), (Henley, et al., 2006) and sudden death (Lyle, et al., 2012). This last study argued that longer races may contribute to develop fatal arrhythmias due to severe metabolic derangements.

3.4.2 Risk Factors common to models for Racecourses A, B and Racecourses B+C

Field size

The current study showed that there is a relationship between the number of runners in the race and the likelihood of a start ending in fatality. Odds of fatality increased for each extra runner in the race, this may be due to the fact that when there are more competitors the likelihood of interaction between them increased. Previous studies demonstrated that increased risk by extra runner in a race may be due to the fact that with more competitors in the race there is an increased total amount of total horse time spent at risk (Parkin, et al., 2004b), (Parkin, et al., 2005).

3.4.3 Risk Factors common to models for Racecourses B and Racecourses B+C

Declared Authorized Medication

Racing in Latin America varies as regards authorized medication for race days. It is strictly forbidden to submit a horse to undergo any pharmacological treatments of any nature, except from those specifically authorised by the Racing Committee. On request, the use of monodrug medication whose active components are either furosemide or phenylbutazone, is authorized. This authorization varies amongst Latin American countries and has been modified in the last few years. It will be detailed for the country to which Racecourse B and C belong, for FS and FB separately.

FS regulatory changes and actual status: Until the year 2012, FS was authorized in every race. In the year 2013 its use was banned in Group I and Group II races (most important races of the calendar). In the year 2014 its used was also banned in Group III and Listed raced (second most important races of the calendar).

FB regulatory change and actual status: Until the year 2009 FB was authorized for horses older than 3.5 years old, with the exception of Group Graded (Group I, II and III) and Listed races. In the year 2010 this changed and FB became forbidden in horses up to 4 years old and not only Group Graded and Listed races but in Non-Grade Classic races as well (all Black Type races). Horses can be medicated with FB as long as they are 4 years old or older, and competing in non-Black Type Races.

For each horse that runs under any of these medications a declaration must be made prior to every race to the veterinary department, that notifies the Racing Authorities. Once this is declared it becomes public information for gambles and stays in the racing system database.

For this study, information about authorized declared medication was categorized into two groups. Horses that declared to run using either FB or FF, and horses that declared to run without medication or only with the use of FS. The first group (FB or FF) represented a significant greater risk for MSI than the second one (FS or none). Table 3-29 shows frequency of fatalities per 1000 starts and number of fatalities. This is also represented in Figure 3-3. Fatality prevalence has always been remarkably lower in horses that ran declaring only FS or no medication at all than FB/FF group during the whole study period.

As far as we are aware, it is the first time such association is demonstrated. The increased odds of fatality for the FB/FF group is probably because those horses need anti-inflammatories or analgesics to have a good performance or to make it to the race. This could be due to clinical or subclinical pre-existing injuries or pain. Thus phenylbutazone administration may allow horses to continue training and racing, accumulating damage to their musculoskeletal structures and increasing the odds of fatalities due to fatal MSI during performance.

Running under medication is strictly restricted to the races mentioned above and is strictly forbidden in any other races. It is worth mentioning that its presence (FB and/or FS) in the horse’s urine or blood where it has been declared (in races that allow its use) is not always confirmed. Trainers may declare the use of phenylbutazone even though if they didn’t give it the day of the race but days before, in training. This would support the theory that the risk is due to the fact that horses that have been declared to run under medication is because they need the analgesic and anti-inflammatory effects of the substance to run or train. Factors that could confound with this result such as race type and age were also included in the model but were not significant for this outcome.

It is plausible to hypothesise that the renal and systemic hemodynamic effect of furosemide on the horse could be involved in some of the sudden death cases, but such association was not demonstrated in this study.

As regards Racecourse D, authorised medication only included furosemide (FS) since the use of phenylbutazone (FB) for racing is forbidden in every category and every age in that racecourse. In the Univariable table for racecourse D there are three medication categories: FS, FS(1) and FS(2). Furosemide administration is done by regulatory veterinarians in Racecourse D. FS(1) corresponds to horses that have received Furosemide for the first time. After that first administration they belong to FS category and will receive it in every race. If a horse leaves that category but then decides to run under furosemide again will be specified as FS(2), and once inside that category will receive furosemide for every race as FS.

No association was found between fatalities and medication with FS in Racecourse D.

Table 3-29: Frequency of fatalities per 1000 starts and number of fatalities and starts per year in the different medication categories, with 95% CI.

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
	TOTAL STARTS	15492	15545	17023	17384	18340	19967	19009	18604	18843	21117	181324
Racecourse B	FB or FF Starts	12156	12162	13473	13701	14002	12666	12211	11182	11731	12950	126234
	FB or FF Fatalities	**7**	**8**	**14**	**12**	**6**	**11**	**12**	**11**	**10**	**17**	**108**
	per 1000 starts	**0.58**	**0.66**	**1.04**	**0.88**	**0.43**	**0.87**	**0.98**	**0.98**	**0.85**	**1.31**	**0.86**
	95% CI	0.28-1.19	0.33-1.30	0.62-1.74	0.50-1.53	0.20-0.93	0.49-1.55	0.56-1.72	0.55-1.76	0.46-1.57	0.82-2.10	0.71-1.03
	FS or None Starts	3336	3383	3550	3683	4338	7301	6798	7422	7112	8167	55090
	FS or None Fatalities	**2**	**0**	**2**	**2**	**1**	**0**	**2**	**4**	**3**	**3**	**19**
	per 1000 starts	**0.60**	**0.00**	**0.56**	**0.54**	**0.23**	**0.00**	**0.29**	**0.54**	**0.42**	**0.37**	**0.34**
	95% CI	0.16-2.18	0.00-1.13	0.15-2.05	0.15-1.98	0.04-1.30	0.00-0.53	0.08-1.07	0.21-1.39	0.14-1.24	0.12-1.08	0.22-0.54
Racecourse B+C	TOTAL STARTS	15492	15545	17023	17384	35106	37272	35043	36324	36773	37120	283193
	FB or FF Starts	12156	12162	13473	13701	26938	24088	22713	22770	22507	23162	193750
	FB or FF Fatalities	**7**	**8**	**14**	**12**	**13**	**15**	**16**	**24**	**12**	**24**	**145**
	per 1000 starts	**0.58**	**0.66**	**1.04**	**0.88**	**0.48**	**0.62**	**0.70**	**1.05**	**0.53**	**1.04**	**0.75**
	95% CI	0.28-1.19	0.33-1.30	0.62-1.74	0.50-1.53	0.28-0.83	0.38-1.03	0.43-1.14	0.71-1.57	0.31-0.93	0.70-1.54	0.64-0.88
	FS or None Starts	3336	3383	3550	3683	8168	13184	12330	13554	14266	13958	89443
	FS or None Fatalities	**2**	**0**	**2**	**2**	**3**	**7**	**5**	**9**	**7**	**4**	41
	per 1000 starts	**0.60**	**0.00**	**0.56**	**0.54**	**0.37**	**0.53**	**0.41**	**0.66**	**0.49**	**0.29**	**0.46**
	95% CI	0.16-2.18	0.00-1.13	0.15-2.05	0.15-1.98	0.12-1.08	0.26-1.10	0.17-0.95	0.35-1.26	0.24-1.01	0.11-0.74	0.34-0.62

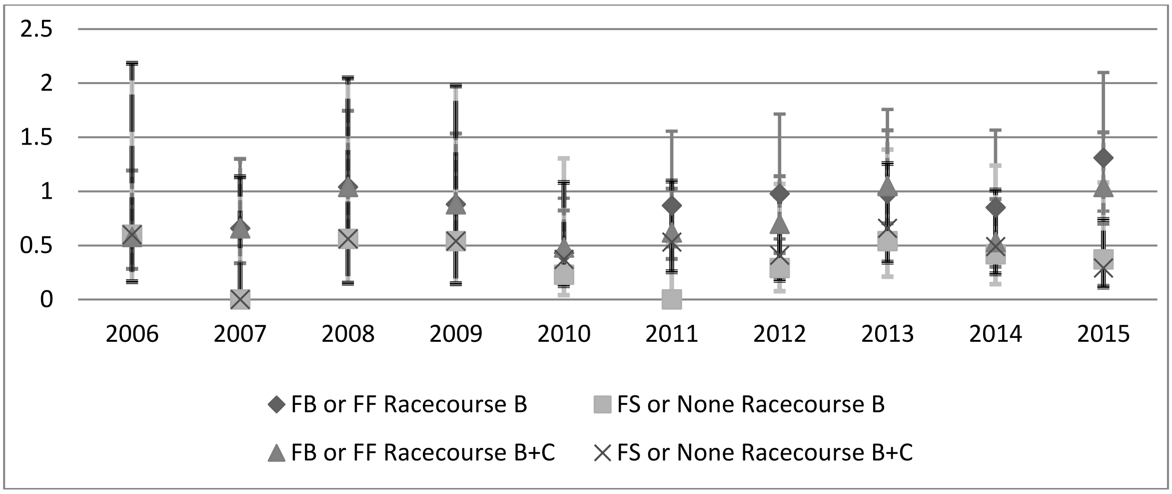

Figure 3-3: Figure showing the frequency of Fatalities per 1000 starts each year for the different medication categories. (With error bars indication 95% CI).

3.4.4 Risk Factors common to models for Racecourses C, D and Racecourses B+C

Horse weight

Horse weight was significantly associated with the risk of fatality in this investigation for racecourse C, D and for B+C model. For those racecourses the odds of suffering a fatality increased per extra 10 kilograms in the horse weight. For racecourse C and models B+C horses with a higher mean body weight at race time, had a higher risk than horses with a lower body weight. For racecourse D this association was for horses that had a body weight over 490 kilograms. Those horses represented a higher risk of fatality than horses under 490 kilograms. This variable has been published as a risk for superficial digital tendon injuries (Takahashi, et al., 2004) but not as a risk factor for fatalities. Vertical ground reaction forces on the hind limbs increase when horses have added weight on their backs (Clayton, et al., 1999). These studies could explain the fact that extra load for horses limbs could result in a fatal MSI. No association has been demonstrated between horse weight and sudden death.

It is important to mention that during this study period appropriate detection of anabolic steroids was not fully accomplished in Latin America. This fact could also be related to this risk factor. Even though the use of any anabolic steroid is strictly forbidden in racing in Latin America, appropriate means to detect this substances in the anti-doping control were not available during the study period. It might be possible that many of these horses could have been medicated with anabolic steroids. The effect of these substances on bone density and behaviour alterations could also influence the risk of fatalities such as fatal MSI or accidents that could lead to central nervous system trauma.

3.4.5 Other Risk factors for Racecourse C

Previous injuries

For racecourse C results indicated that odds of suffering a fatality were more than eight times bigger for horses having previous injuries recorded by the official veterinary service. Many studies have demonstrated that horses with previous lesions are more likely to suffer a serious injury and that post-mortem findings are consistent with the fact that fatal MSI are, in many cases, a consequence of cumulative damage. Horses that had a SDF tendinopathy previously diagnosed at the racecourse were found to be approximately 20 times more likely to sustain another SDF lesion during racing (Reardon, et al., 2012). Many racehorse injuries are the product of long term insidious skeletal and soft tissue damage resulting from repeated loads during high speed exercise (Estberg, et al., 1995). Post mortem findings such as greater eroded surface in the subchondral bone of fractured area also support the explanation of this finding. Focal bone loss as a result of greater surface erosion could contribute to fracture propagation (Whitton, et al., 2013). If we take into account that studies support the fact that even subclinical injuries imply a greater risk, we can conclude that a clinical finding, obvious lameness or palpable pain would indeed suggest a much greater risk of suffering a fatality. Pre-existing pathologic conditions play an important role in racing injuries. It has been suggested that regulatory veterinarians can identify horses during prerace physical inspection that have an increased risk of injury during racing (Cohen, et al., 1997).

Records of previous injuries in racecourses in Latin America are very few, confidential and available only for the racecourse where it was recorded. We believe that if this information was shared between racecourses on the same region that host the same competitors, records would improve and it would help further minimise the risk of fatal injury. Records of previous injuries from private veterinarians (i.e. those incurred during training) are not available for official veterinarians.

3.4.6 Other Risk factors for Racecourse D

Jockey weight

Results indicated a horse ridden by jockeys over 57 kilograms were more likely to suffer a fatality in racecourse D than horses ridden by jockeys of 57 kilograms or less. As it has been demonstrated, increased weight would increase the load on the horses forelimbs (Takahashi, et al., 2004), making horses more likely to suffer an injury. Vertical ground reaction force on the limbs increases when horses have a jockey or sandbags on their backs (Clayton, et al., 1999). The heavier the jockey, the bigger the vertical ground reaction forces on the limbs, meaning a bigger risk for suffering a fatality. Even though jockey experience has also been evaluated in racecourse D model accounting for any confounding with this variable, it would be interesting to have more information available about jockey. Their level of training, nutrition and use of diuretics or other substances that could affect their performance could be taken into account for further investigation. That information was not available in this investigation.

Jockey Experience

For racecourse D, results indicated that risk of fatality increased when a horse was ridden by a learner jockey. it is possible that non-professional jockeys are less able to recognise a problem in the horse they are riding. This variable has been demonstrated at the level of the race (Parkin, et al., 2005) as a risk factor for fatal lateral condylar fracture of the third metacarpus/metatarsus in UK racing. Such association explains that a professional jockey would have enough experience to recognise any sign of discomfort and pull up a horse before the race ends, potentially avoiding a fatality. In the current investigation this variable was only available for analysis for racecourse D. It could be analysed for other racecourses in OSAF jurisdiction in future investigations.

Cumulative distance raced

Results indicated that horses with a cumulative racing distance between 3600 to 7400 meters had reduced odds of fatality in comparison with horses with a cumulative racing distance between 7400 to 13000 meters.

The association of injury with cumulative high-speed exercise appears to vary among regions. It was suggested that in Kentucky, injured horses had significantly less cumulative high-speed exercise than control horses (Cohen, et al., 2000). On the other hand, in California, high total and high average daily rates of high-speed exercise distance accumulation were associated with higher risk of fatal fracture (Estberg, et al., 1996a), and the relative risk for racing fatal MSI was significantly greater for those horses which ran excessive 2-month, cumulative racing and time workout distances (Estberg, et al., 1995). These last results are compatible with the belief that many racehorse injuries are the product of long-term insidious skeletal and soft tissue damage resulting from repeated loads during high-speed exercise. Increasing exercise distances at canter and high speed in short periods were associated with an increasing risk of dorsometacarpal disease in young thoroughbred racehorses in the UK, but increasing cumulative exercise distance since entering training were associated with a decreasing risk of disease (Verheyen, et al., 2010). Too many successive, repetitive loading cycles may lead to fatigue damage in the dorsal cortex of the third metacarpal bone and induce an exaggerated remodelling response. In the UK, it has also been demonstrated that horses doing no gallop work during training were at significantly increased risk of fracture on the racecourses (Parkin, et al., 2005), and it was suggested that the minimum distance galloped should be between 805 to 2012 meters per week (Parkin, et al., 2006b). In Australia, increasing the average distance trained at high speed was associated with an increased risk of injury (Cogger, et al., 2006). It has been demonstrated that under conditions of repetitive loading there is approximately double the level of surface erosion at the fatigue fracture site (Estberg, et al., 1995).

Our results are consistent with findings that support the increased risk at longer high-speed cumulative distance, since the distances taken into account for this study are those covered in races. However, the lack of training records affects our ability to make firm interpretations of our results since we are not taking into account the high-speed exercise cumulative distance or gallop work at training. Real high-speed cumulative distance may therefore be somewhat different to that recorded and analysed in the current study. Further investigation is needed to fully interpret this risk factor.

3.5 Limitations of this study

A limitation is the fact that the incidence of sudden death and central nervous system fatal trauma are very low in this study. It is therefore not possible to be certain that the risk factors identified in our models apply to these particular outcomes. Further investigations are needed to provide appropriate risk factors which are exclusive for sudden death. However, this will not be possible unless the incidence of these outcomes increases dramatically because there will not be sufficient statistical power to provide any degree of certainty in such an analysis.

The fact that starts information in different racecourses (other than those four racecourses included in the study) at which the same competitors run was not available for this study is also a limitation. Future work should aim to include data from more OSAF racecourses as it is very important to have accurate information about the total amount of starts a horse had in order to analyse results regarding a horse’s racing history and layups.

A lack of official training records is also a limitation of this study since having that information could help understand and explain some of our results, such as cumulative distance, or even discover new ones.

Necropsies are not regulated in South America, so post mortem information is variable between racecourses. More accurate information about injuries and pre-existing subclinical lesions could help improve future investigations.

3.6 Conclusion

This research has identified some already determined risk factors for fatalities in racing in South America. It has also determined new risk factors, reinforcing the importance of not only conducting ‘(inter)national’ analyses from as many tracks as possible but also the value of individual track analyses where there are sufficient data to provide adequate statistical power. This study is the first to clearly demonstrate an association between racing, having recently been administered phenylbutazone, and the risk of fatality. The next challenge is to attempt to turn this information into policy or regulatory change in the racing jurisdictions in which such practices are permitted.

4. General Discussion

4.1 Introduction

The goal of this research was to identify risk factors at OSAF jurisdiction racecourses that could be modified to reduce the risk and/or prevalence of injuries where possible. It is important that advice to minimise risk is given after appropriate investigations and in a clear way. Sometimes they involve political decisions and changes in regulation policies such as changing authorized medication policies, but there are also many things that official veterinarians can do to reduce risk in racing. For example, using appropriate pre-race examinations of the competitors and competent “vet lists” to avoid injured horses to continue running. Having this in mind, this chapter will review the prevalence of (fatal) injury and identified risk factors at OSAF jurisdiction.

4.2 Prevalence

Estimates of the prevalence of fatality allows comparison with the situation in other regions and defines a baseline in this research. Table 4-1 compares fatality prevalence per 1000 starts of UK (from 2000 to 2009), USA (from 2009 to 2015) and OSAF jurisdiction (from 2005 to 2015).

Table 4-1: Comparative fatality prevalence of flat horseracing between UK, USA and OSAF through different study periods.

Region	UK	USA	OSAF
Period	2000 to 2009	2009 to 2015	2005 to 2015
Fatalities/1000 starts	**0.8**[6]	**1.87**[7]	**0.62**

It might be inappropriate to compare prevalence when it doesn’t belong to the same study period. Nevertheless Table 4-1 evidences differences in fatalities per 1000 starts between regions and between time periods. We cannot discount the possibility that these differences are due to the difference in efficiency of recording fatalities at the different regions, changes in policies seeking to reduce risks during each study period and of course cultural differences.

Latin America is characterized for being a region with an extensive countryside area and a very respectful culture regarding horses. This attitude results in injured

[6] (Reardon, 2013)

[7] The Jockey Club. Available at www.jockeyclub.com

horses being given every opportunity to continue living even though they might not return to sport, reducing the number subjected to euthanasia. For example, the majority of sesamoid bone fractures, in our records, were considered a non-fatal injury. On top of this, the estimate of fatality prevalence might also be low as fatalities recorded are only those in which the horse dies or is immediately euthanized by the official veterinary service. Only in some cases do they include euthanasia of horses living at the racecourse 24 hours after the injury. Horses are not yet insured in the region, which may also contribute to a low prevalence of euthanasia; since there is no economic profit from the death of the horse.

It is also interesting to observe differences in MSI and fatality prevalence between racecourses and within racecourses through the study period at OSAF jurisdiction tracks. Table 4-2 shows the prevalence per 1000 starts for MSI and fatality at the four OSAF racecourses included in this study.

Table 4-2: Fatalities and MSI prevalence per 1000 starts each year, subdivided into the different Racecourses.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Study Period
FATALITIES/1000 STARTS												
Racecourse A	0.53	1.04	0.51	0.53	0.21	0.6	0.45	0.47	0.18	0.38	0.76	0.51
Racecourse B		0.58	0.51	0.94	0.81	0.38	0.55	0.74	0.81	0.69	0.95	0.7
Racecourse C						0.54	0.63	0.44	1.01	0.33	0.5	0.58
Racecourse D						1.03	0.53	0.51	0.25	0.89		0.64
MSI/1000 STARTS												
Racecourse A	2.02	2.28	1.83	1.58	0.94	1	1.08	1.22	0.79	1.14	1.99	1.43
Racecourse B		1.61	1.22	2.35	2.36	1.15	2.05	1.89	2.04	2.23	2.65	1.98
Racecourse C						1.73	1.56	2.12	2.93	1.89	1.62	1.98

There are considerable differences between the prevalence by year and by racecourse. In most years, where data was available for all racecourses, the risk of MSI and fatalities was lower at Racecourse A and in some cases for fatalities in Racecourse C. These differences might be due to the way in which official veterinarians record injuries at the different tracks, changes in veterinary personnel during the study period and perhaps also changes in the official pre-race examination on race days. It is however, also plausible that some racecourses are inherently safer than others.

As mentioned before, the aim of this study was to identify risk factors and reduce the risk and/or prevalence when possible. It is important to point out that prevalence of fatality, in Latin America, is quite low. Nevertheless changes can be implemented to keep reducing risk, even though this would not necessarily mean a considerable reduction in the prevalence of fatality. On the other hand, applying appropriate changes could mean a reduction in non-fatal MSI prevalence in the region.

It is important to mention that available data for this investigation was from four OSAF racecourses only. Similar studies should be conducted on the other OSAF racecourses that could not contribute information to this investigation. It would not be correct to extrapolate the findings of this study to all OSAF tracks. Our results are encouraging other racecourses to start collecting data for future investigations.

4.3 General results

Many models have been run in this research to identify risk factors for two different outcomes: MSI and fatalities. Many results are common to both outcomes while there also were some differences between them. Table 4-4 shows common risk factors for MSI and fatalities and also exclusive risk factors for each studied outcome.

Table 4-3: Risk factors determined for each outcome at OSAF jurisdiction

RISK FACTORS AT FOUR OSAF JURISDICTION RACECOURSES		
EXCLUSIVE FOR MSI	***COMMON FOR MSI AND FATALITIES***	**EXCLUSIVE FOR FATALITIES**
Age Season of the year Racing surface Gender Layups Layup days Race configuration Starts career	***Horse weight*** ***Running distance*** ***Authorized medication*** ***Previous injuries***	Field size Jockey weight Jockey experience Cumulative distance raced

Similarities in risk factors for both outcomes are due to the fact that most of the causes of fatality are musculoskeletal injuries. Nevertheless it is very important to run as many analyses as possible with different outcomes in case a new, important and specific risk factor for a particular cause of fatal injury is discovered in the region. Risk factor that are exclusive for MSI might indirectly also help prevent fatalities since they would affect previous injuries variable which is in fact a risk factor for fatalities as well. Also, many MSI are fatal. The fact that MSI risk factor list is larger could be due to the reason that the outcome is not as specific as fatalities and also due to increased statistical power afforded by the larger number of cases in the MSI analysis.

It is also important to mention that not every risk factor present in Table 4-3 is applicable to each of the four OSAF racecourses. Table 4-4 shows risk factors for each outcome per each participating OSAF racecourse. Grey shades indicate different outcomes, MSI, fatalities and both outcomes from lighter to darker grey.

Table 4-4: Risk factors for different outcomes per OSAF Racecourse

<table>
<tr><th colspan="6">RISK FACTORS FOR RACECOURSE:</th></tr>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>B+C</th></tr>
<tr><td rowspan="6">MSI</td><td rowspan="3">Horse weight</td><td rowspan="2">Horse weight</td><td rowspan="2">Running distance</td><td rowspan="6">NO DATA</td><td>Age</td></tr>
<tr><td>Season of the year</td></tr>
<tr><td>Running distance</td><td>Age</td><td>Racing surface</td></tr>
<tr><td rowspan="3">Age</td><td>Age</td><td>Season of the year</td><td>Gender</td></tr>
<tr><td>Racing surface</td><td>Race configuration</td><td>Layups</td></tr>
<tr><td>Gender</td><td>Starts career</td><td>Layup days</td></tr>
<tr><td rowspan="5">FATALITIES</td><td rowspan="5">Field size</td><td rowspan="5">Field size</td><td rowspan="5">NONE</td><td>Horse weight</td><td rowspan="5">Field size</td></tr>
<tr><td>Running distance</td></tr>
<tr><td>Jockey weight</td></tr>
<tr><td>Jockey experience</td></tr>
<tr><td>Cumulative distance raced</td></tr>
<tr><td rowspan="3">BOTH</td><td rowspan="3">Running distance</td><td rowspan="3">Authorized medication</td><td rowspan="2">Horse weight</td><td rowspan="3">NO DATA</td><td>Horse weight</td></tr>
<tr><td>Running distance</td></tr>
<tr><td>Previous injuries</td><td>Authorized medication</td></tr>
</table>

As Table 4-4 shows, there are many risk factors for the studied outcomes that could be determined throughout this research. Some of them, already identified in other regions of the world (like age, gender, running distance, etc.) have also been confirmed as risk factors for the OSAF jurisdiction. Variables like age could have been collapsed in some racecourses in this study. For Racecourse A, the age variable could have been collapsed into 2-year old versus older horses using 2-year old as the reference category; it will be considered for future investigations. Some others (like horse weight and season of the year) that were identified as risk factors for tendinopathy in Japan and UK respectively, were also confirmed to be risk factors in the OSAF jurisdiction. Horse weight was identified as a risk factor in all participating racecourses, and not only for MSI in general but in many racecourses as a risk factor for fatality as well. Season of the year, was identified as a risk factor at Racecourse C for MSI in general. Authorized medication was identified as a risk factor for MSI and fatality at Racecourse B and Racecourse B+C. As far as we know this is the first time that a risk factor related to medication policy has been determined, and the impact of this finding could be very significant for horseracing industry, particularly in those regions where medications are permitted on race-day. This could encourage introducing policies that seek to reduce the number of races in which medication is authorized, and in a future ban authorized medication in racing.

Our findings clearly show how important it is to conduct individual track analyses where there are a sufficient number of cases as well as doing the more statistically powerful analyses for combinations of tracks within countries or continents. This led us to discover new risk factors in the studied region.

It is interesting to compare the odds ratio for variables that were detected to be risk factors for both outcomes. For example, for authorized medication the odds of MSI for Racecourse B was 1.79 times greater for FB or FF compared to FS or non-medicated horses and for Racecourse B+C odds ratio was 1.45 greater. When this same variable was analysed using fatality as an outcome the odds ratios were bigger; 2.44 for Racecourse B and 1.59 for Racecourse B+C.

In the case of previous injuries, there are not many records of minor injuries like tendinopathy or lameness (without a definitive diagnosis) in the different OSAF Racecourses. Racecourse C was the only one that had sufficient records to analyse this particular variable for both outcomes, although confidence interval is considerably wide due to the low number of cases. This variable depends mostly on criteria of official veterinarians working at the track and incidents recorded on race days and could be much more informative if ‘in training’ injuries were also available.

4.4 Global and regional relevance

This study provides important information for the racing industry to monitor racetrack fatalities and MSI and evaluate intervention strategies in an attempt to reduce their incidence. These results may facilitate the development of effective strategies to improve overall safety of horses and jockeys in OSAF jurisdiction.

Authorized medication identified as a risk factor represents a very important finding with not only regional but global impact. As far as we know it is the first time this has been demonstrated, which may encourage modifying medication policies in other jurisdictions worldwide.

It is important to mention that during this research there were some strategy developments and changes implemented in some of OSAF racecourses taking into consideration some of our findings. Pre-race examination became more important, seeking pre-existing conditions amongst the competitors. Complementary studies and good health certificates by private veterinarians are being solicited in remarkably poor performance cases or lameness at the end of the race, banning competition until they are provided. There is a proposal to create a “Vet list” amongst racecourses that belong to the same country to prevent horses at significant risk from competing in the region. In cases in which risk cannot be reduced immediately, like races in which phenylbutazone is allowed, veterinary service is prepared and ready to act in case of an injury occurring, like in any other race, but with the knowledge that risk is higher.

Necropsies are being done at some racecourses and other ones are being encouraged to start performing them. Pre-existing injuries can sometimes be observed during necropsy, which supports the facts that many risk factors belong to horses that had accumulated injuries or micro trauma throughout their racing and training career. This enforces the fact that many fatal injuries could be prevented, if the pre-existing injury can be detected early.

4.5 Limitations of this study

Limitations of this study, already mentioned in Chapter 2 and Chapter 3 include the fact that starts information in different racecourses in which the same competitors run was not available for this study. This could mean that horse’s racing history and layup information is likely to be incomplete.

Lack of official training records is also an important limitation of this study since it also contributes to the horse’s history.

Lack of necropsy information for fatal injuries or sudden death also implies a limitation of important information in this study.

Variable veterinarian criteria in the different racecourses or through the study period are also a potential limitation, as is lack of previous injuries records in some racecourses or low records of sudden death and central nervous system fatal trauma in fatalities outcome.

4.6 Future research

Based on findings on this research, further investigation for different variables not included in these analyses, or new racecourses from OSAF jurisdiction should be conducted in the future. Some already studied variables in this investigation, like age, could be collapsed to improve models. It would also be important to have more years of data from some participating racecourses to identify more risk factors.

It would also be very interesting to conduct an investigation including additional diagnosis aids at the racecourses and post-mortem findings to clarify the diagnoses of fatal and non-fatal injured horses during racing.

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