UNIVERSITI PUTRA MALAYSIA

RETROSPECTIVE STUDY ON THE INCIDENCE OF EXERCISE-INDUCED PULMONARY HAEMORRHAGE (EIPH) IN RACING THOROUGHBREDS IN SELANGOR TURF CLUB (STC) FROM SEPTEMBER 2017 TO AUGUST 2022

TAN JIN YU

lp
FPV 2022 4

RETROSPECTIVE STUDY ON THE INCIDENCE OF EXERCISE-INDUCED PULMONARY HAEMORRHAGE (EIPH) IN RACING THOROUGHBREDS IN SELANGOR TURF CLUB (STC) FROM SEPTEMBER 2017 TO AUGUST 2022

TAN JIN YU

A project paper submitted to the
Faculty of Veterinary Medicine, Universiti Putra Malaysia
In partial fulfilment of the requirement for the
DEGREE OF DOCTOR OF VETERINARY MEDICINE
Universiti Putra Malaysia
Serdang, Selangor Darul Ehsan.

2022/2023

CERTIFICATION

It is hereby certified that we have read this project paper entitled “Retrospective Study on the Incidence of Exercise-Induced Pulmonary Haemorrhage (EIPH) in Racing Thoroughbreds in Selangor Turf Club (STC) from September 2017 to August 2022”, by Tan Jin Yu and in our opinion, it is satisfactory in terms of scope, quality and presentation as partial fulfillment of the requirement for the course VPD 4999 - Project.

_____

ASSOC. PROF. DR. NORANIZA MOHD ADZAHAN
DVM (UPM), MVM (UPM), PHD (UPM)
Lecturer,
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Supervisor)

_____

DR. SHRI KANTH
DVM (UPM)
Veterinary Surgeon,
STC Equine Hospital and Diagnosis Centre
Selangor Turf Club
(Co-supervisor)

ACKNOWLEDGEMENTS

I wish to express my deep appreciation to the many people who have helped with this project. First and foremost, I would like to thank Selangor Turf Club for their kind contribution of data, which enabled this retrospective analysis.

Next is my supervisor, Associate Professor Dr. Noraniza Mohd Adzahan. I am also very grateful to have Dr. Shri Kanth as my co-supervisor, who has guided me a lot throughout the project. Their expertise, encouragement and constructive opinions on the flow of the project and the write-up of the project paper were vital. Meanwhile, I also acknowledge the support from the staff at the Selangor Turf Club Equine Hospital.

Special thanks to my friends, including Puteri Rose Camelia binti Roselan, Zulfitri Naim bin Abdul Rahim and Tan Ying Xing for their help and support during my final year project. Last but not least, I extend my sincere gratitude to my family for their constant encouragement and understanding.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRAK

Abstrak daripada kertas project yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada keperluan kursus VPD 4999-Projek.

PEMERIKSAAN RETROSPEKTIF MENGENAI INSIDENS EXERCISE-INDUCED PULMONARY HAEMORRHAGE (EIPH) DALAM PERLUMBAAN KUDA TORUGBRED DI KELAB LUMBA KUDA SELANGOR DARI SEPTEMBER 2017 HINGGA OGOS 2022

Oleh

Tan Jin Yu

2022

Penyelia: Prof. Madya Dr. Noraniza Mohd Adzahan

Exercise-induced pulmonary haemorrhage (EIPH) adalah masalah pernafasan yang kerap berlaku dalam kuda lumba. Walau bagaimanapun, faktor risiko keadaan ini tidak ditakrifkan dengan jelas. Tujuan pemeriksaan retrospektif ini adalah untuk mengenal pasti hubungan kejadian EIPH dalam perlumbaan kuda Torugbred dengan umur, jarak perlumbaan, purata suhu persekitaran dan kelembapan relatif. Prestasi kuda lumba yang positif EIPH juga diteliti. Sejumlah 472 rekod kuda Torugbred yang mengalami EIPH di Kelab Lumba Kuda Selangor dari September 2017 hingga Ogos 2022 dianalisa secara deskriptif dan diuji menggunakan kolerasi Spearman rho. Ke semua kuda yang mengalami EIPH selepas perlumbaan menunjukkan simptom epistaksis atau gangguan

pernafasan disebabkan oleh pendarahan dalam paru-paru. Keputusan kajian ini menunjukkan terdapat hubungkait yang signifikan ($p<0.05$) antara EIPH dengan jarak perlumbaan ($r=-0.327$) dan purata suhu persekitaran ($r=0.194$). Tiada korelasi di antara EIPH dengan umur dan kelembapan relatif. Telah terbukti EIPH menjejaskan prestasi keseluruhan kuda lumba. Lebih daripada separuh (56.03%) kuda positif EIPH mengalami penurunan penarafan. Bagi kedudukan penamat perlumbaan, hanya 6.56% daripada 442 ekor kuda yang mengalami EIPH memenangi tempat pertama, kedua atau ketiga dalam perlumbaan. Selain itu, 36.23% daripada kuda mempunyai EIPH berulang dan 60.59% telah dibatalkan pendaftaran daripada perlumbaan kuda dalam tempoh 5 tahun kajian yang dijalankan. Kesimpulannya, pengurusan yang baik bagi faktor risiko yang dikenalpasti dalam kajian ini dapat membantu mengurangkan kekerapan EIPH, di mana EIPH jelas menjejaskan prestasi kuda lumba dan menyebabkan implikasi kewangan ke atas industri lumba kuda.

Kata kunci: *kuda lumba, EIPH, faktor risiko, prestasi*

ABSTRACT

An abstract of the project paper presented to the Faculty of Veterinary Medicine in partial fulfilment of the course of VPD 4999-Project.

RETROSPECTIVE STUDY ON THE INCIDENCE OF EXERCISE-INDUCED PULMONARY HAEMORRHAGE (EIPH) IN RACING THOROUGHBREDS IN SELANGOR TURF CLUB (STC) FROM SEPTEMBER 2017 TO AUGUST 2022

by

Tan Jin Yu

2022

Supervisor: Assoc. Prof. Dr. Noraniza Mohd Adzahan

Exercise-induced pulmonary haemorrhage (EIPH) is a common respiratory condition in racehorses but the risk factors are not clearly defined. The aim of this retrospective examination was to identify the association of the occurrence of EIPH in racing Thoroughbreds with age, race distance, average ambient temperature and relative humidity. The performance of the EIPH-positive horses was also examined. A total of 472 flat-racing Thoroughbreds with EIPH in the record of Selangor Turf Club (STC) from September 2017 to August 2022 were analysed descriptively and tested using Spearman's rho correlation. All horses diagnosed with EIPH post-race had epistaxis or respiratory distress associated with pulmonary haemorrhage. The result revealed significant associations ($p<0.05$) between EIPH with race distance ($r=-0.327$) and

average ambient temperature (r=0.194). No correlation was identified between EIPH with age and relative humidity. EIPH was shown to impair the overall racing performance of the horses. More than half (56.03%) of EIPH-positive horses experienced a decrease in rating. For the finishing position, only 6.56% of the 442 horses won the first three placing in the race with the incidence of EIPH. With regards to recurrence and deletion, 36.23% of the horses had recurrent EIPH and 60.59% were deregistered from horse racing within the 5 years of study duration. In conclusion, proper management of the risk factors identified in the present study may be helpful in reducing the frequency of EIPH, which clearly compromises racehorse performance and has financial implications for the horse racing industry.

Keywords: *racehorse, EIPH, risk factors, performance*

1.0 INTRODUCTION

Exercise-induced pulmonary haemorrhage (EIPH) affects a lot of horses involved in equestrian activities that require bursts of intense activity, such as racehorses all over the world. It is defined as the presence of blood in the airways due to pulmonary haemorrhage following strenuous exercise (Davis, 2018). The prevalence of EIPH varies depending on the type of exercise, the criteria used to define EIPH, the population of horses tested and the frequency of examinations. Approximately 43 to 75% of Thoroughbred racehorses show blood within the trachea following a single examination using tracheobronchoscopy performed within 2 hours of racing. The prevalence of EIPH rises to more than 85% with repeated examinations (Sullivan and Hinchcliff, 2015). Despite the condition's considerable prevalence, the risk factors for EIPH have not been well defined. Since prophylaxis such as race-day furosemide is not practised in Malaysia, proper management of the risk factors can be useful to reduce the severity and frequency of EIPH in racehorses.

In this study, the correlation between age, race distance, average ambient temperature and relative humidity with the occurrence of EIPH was identified. Besides, the change in the rating of the horse with EIPH from September 2017 to August 2022 was evaluated. The percentages of recurrence and deletion were calculated. The finishing positions of the EIPH-positive horses in the race with the incidence of EIPH were also determined. This information helped to illustrate the effect of EIPH on racing performance. In essence, this paper gave an insight into the risk factors and the effect of EIPH on horse racing in Selangor Turf Club (STC), Malaysia.

2.0 LITERATURE REVIEW

2.1 PATHOPHYSIOLOGY OF EIPH

In order to effectively minimize EIPH cases, understanding the pathophysiology of the condition is crucial. A thorough search of the relevant literature yielded two theories about the mechanism that causes EIPH: stress failure of pulmonary capillaries (West *et al.*, 1993; Erickson *et al.*, 2010) and locomotory impact-induced trauma on the lungs (Schroter *et al.*, 2010; Newton *et al.*, 2010). Although two theories were proposed, the theory of high positive intraluminal pressure together with high negative alveolar pressure causing the stress failure of the pulmonary capillaries during maximal exercise was more widely studied and accepted.

According to the literature, the capillary transmural pressure (Ptm) required to cause stress failure of pulmonary capillaries is between 75mmHg and 100mmHg (Birks *et al.*, 1997), while the finding of Erickson *et al.* (2010) supported that EIPH is possible in racehorses as their pulmonary artery pressure (PAP) will rise to about 80mmHg to 150mmHg in strenuous exercise. Not only that, extremely negative alveolar pressures are necessary to produce peak inspiratory flow rates of about 120L/s against the resistance produced by the horse's long extrathoracic airways (Poole and Eriskson, 2016). The combination of high pressures acting across the thin blood-gas barrier causes the rupture of the pulmonary capillaries during strenuous exercise.

Schroter *et al.* (2010) developed a computational model to demonstrate the second theory of the pathophysiology of EIPH. The locomotory impact of the forelimbs produces a localised impulsive load on the chest wall that is transmitted as pressure

waves through the lung. This caused the lesion to be most commonly found at the dorsocaudal region of the lungs because the wave increased in magnitude as the mass of the affected lung tissue decreased towards the dorsocaudal lobe. The latter explained the reason for the tendency of lesion distribution in EIPH that was insufficiently explained by the first theory alone.

2.2 DIAGNOSIS OF EIPH

The diagnosis of EIPH can be made by several methods, including tracheobronchoscopic examination, cytological examination of bronchoalveolar lavage (BAL) or tracheal lavage fluid and observation of epistaxis associated with exercise.

Although tracheobronchoscopic examination was easier and faster, there was a study showing that more false negatives were found when using only endoscopy (Lopez Sanchez *et al.*, 2020). The stains that highlighted the iron-containing pigment such as Prussian blue helped in identifying the hemosiderophages (hemosiderin-laden macrophages) in the BAL sample. The presence of hemosiderin within many of the alveolar macrophages post-exercise was diagnostic for EIPH. The severity of the EIPH can be determined by visual estimation of the amount of bleeding seen in tracheobronchoscopy and can be graded from 0 to 4. Grade 0 was assigned when no blood was observed in the tracheobronchial tree and grades 1 to 4 was allocated for cases with increasing amounts of blood (Birks *et al.*, 2010).

In this study, the diagnosis of EIPH was based on the veterinarian's observation of the presence of epistaxis and the tracheobronchoscopic examination of the horse with

respiratory distress immediately after the race. Horses that have epistaxis following strenuous exercise are usually known as "bleeders" and do not need an endoscopic examination to confirm the diagnosis.

2.3 EFFECT OF EIPH ON RACING PERFORMANCE

EIPH is often associated with the poor performance of the affected horses in races. This idea was researched by Hinchcliff *et al.* (2005) and Crispe *et al.* (2017). Through their studies, both of them agreed that EIPH was linked with impaired performance in Thoroughbred racehorses, especially for severe (grade 4) EIPH. Besides, Sullivan *et al.* (2015) have looked into the long-term effect of EIPH on racehorses' performance. They concluded that there was no correlation between the long-term racing performance of Thoroughbred racehorses and EIPH grades 1, 2 and 3. However, this did not apply when the severity was grade 4. Throughout these studies, it was known that a severe grade 4 EIPH had the greatest impact on the performance of the racehorses.

After an episode of EIPH, the pulmonary capillaries were injured and vulnerable to secondary bacterial infection. In light of this, the bleeders were usually suspended from racing for a period of time for recovery and were given antibiotics if there were signs of infection. With the first episode of EIPH, the horse will be banned from racing for 3 months according to the practice in STC. Then the subsequent episode will have a longer resting period which was 6 months. A chronic bleeder with recurrent EIPH will be permanently deleted due to the welfare issue of continuing racing and its compromised performance.

In short, the impaired performance, necessity for medication and loss of training and racing days due to EIPH have major financial implications for the racing industry.

2.4 PREVENTION OF EIPH

Prophylactic intervention such as the administration of furosemide at least 4 hours before racing has been legally approved for many years by the United States (US) racing industry. However, this practice is forbidden by Article 6 of the International Federation of Horseracing Authorities (IFHA) and the International Federation for Equestrian Sports (FEI). Furosemide as a diuretic might help to dilute or flush out the illegal substance and some also thought that furosemide has other performance-enhancing properties than just prophylaxis for EIPH. Therefore, furosemide has been considered a doping agent by the FEI and most racing authorities in the world (Toutain, 2010), including Malaysia. Other prophylactic interventions are not commonly practised and limited articles are found on other effective drugs for the prevention of EIPH.

Apart from the prophylactic interventions, controlling the risk factors can be an alternative to minimize the severity or frequency of EIPH. Many researchers have studied this topic, but the risk factors remain controversial. For example, two of the commonly studied risk factors discussed in the literature were the age and the sex of the horses. In the studies by Pascoe (1981) and Hinchcliff (2010), they did not find an association between the occurrence of EIPH with age and sex. On the other hand, Takahashi (2001) and Weideman (2003) found that the frequency of EIPH-related epistaxis was significantly associated with age and sex. This could be due to differences in their sample inclusion criteria and EIPH diagnostic method. The latter mainly focused on the epistaxis

related to EIPH, while the former diagnosed EIPH by using a tracheobronchoscopy. Not only that, many other factors such as weight carried, speed of racing, air quality and genetic factors are also being actively investigated. Although many other risk factors might be involved in the development of EIPH, the focus of this study will be on age, race distance, average ambient temperature and relative humidity.

3.0 MATERIALS AND METHODS

A retrospective examination was conducted based on the records of a total of 472 EIPH-positive horses in STC. The related information from September 2017 to August 2022 was retrieved for analysis. All the EIPH-positive horses in the records were the ones that showed epistaxis or respiratory distress related to pulmonary haemorrhage immediately after the race. It can be said to be graded as EIPH severity grade 3 and above. This study did not include mild EIPH with no clinical signs observed.

The data collected included the MRA brand number, name of the horses, age, sex, trainer, rating and status of the horses, track going, finishing position and race distance on the particular race when the EIPH occurred. Besides, the date of the EIPH, the average ambient temperature and the relative humidity on the day, specifically at the time from 12p.m. to 6p.m., which was the period when most of the races in STC were held, were also recorded. Among the 472 cases, all of the cases were used in the analysis for age, ambient temperature, relative humidity and percentages of recurrence and deletion. However, only 445, 448 and 442 cases were included, respectively, for the analysis of the race distance, the rating and the finishing position of the horse due to the incomplete data in the records.

The data were tabulated using Microsoft Excel Spreadsheet Software and analysed using IBM® SPSS® Statistics Software. The change in the rating was grouped into 3 categories: increase, decrease and maintain. Then, the percentage of racehorses in each category was calculated. The proportion of horses with recurrent EIPH and the proportion of horses deleted were also determined.

The presence of correlations between the occurrence of EIPH with age, race distance, ambient temperature and relative humidity were statistically tested. Only the first occurrence of the EIPH recorded from September 2017 to August 2022 for each horse was included in the correlation analysis. The normality of the data was checked using the Kolmogorov-Smirnov or Shapiro-Wilk test to identify whether the data fulfilled the assumption for parametric data. As the result of the Kolmogorov-Smirnov or Shapiro-Wilk test showed that all the data did not conform to normality ($p<0.05$), these data were considered non-parametric. Therefore, Spearman's rho test was used for the analysis of the correlation between these variables and the occurrence of EIPH.

4.0 RESULTS AND DISCUSSION

In Figures 1 to 4, normality tests (Kolmogorov-Smirnov or Shapiro-Wilk) showed that all the data collected for analysis did not conform to normality ($p<0.05$). Therefore, these data violated the assumption of parametric data, which includes that the data must be normally distributed.

In light of that, a non-parametric test, Spearman's rho correlation, was chosen. As shown in Figures 5 to 8, the associations of the number of EIPH cases with the factors including age, race distance, average ambient temperature and relative humidity were tested using the IBM® SPSS® Statistics Software. As the confidence level of this study was at 95%, the correlation will be significant only when $p<0.05$. Although all the Spearman's rho tests showed a correlation coefficient value in the final result, the value was negligible if the $p>0.05$.

To summarise, the results of Spearman's rho test showed that there were significant associations ($p<0.05$) between the occurrence of the EIPH with the race distance and the average ambient temperature. However, no association was found between the development of EIPH with age and relative humidity. The EIPH was also showed to impair the performance of the racehorses after evaluating the change in rating, the finishing position and the percentages of recurrence and deletion.

Figure 1: Normality test for age

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EIPH_CASES	.309	472	.000	.770	472	.000

a. Lilliefors Significance Correction

Figure 2: Normality test for race distance

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EIPH_CASES	.222	445	.000	.861	445	.000

a. Lilliefors Significance Correction

Figure 3: Normality test for average ambient temperature

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EIPH_CASES	.219	472	.000	.933	472	.000

a. Lilliefors Significance Correction

Figure 4: Normality test for relative humidity

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EIPH_CASES	.167	472	.000	.954	472	.000

a. Lilliefors Significance Correction

Figure 5: Spearman's rho correlation test for age

Nonparametric Correlations

Correlations

			AGE	EIPH_CASES
Spearman's rho	AGE	Correlation Coefficient	1.000	.009
		Sig. (2-tailed)	.	.841
		N	472	472
	EIPH_CASES	Correlation Coefficient	.009	1.000
		Sig. (2-tailed)	.841	.
		N	472	472

Figure 6: Spearman's rho correlation test for race distance

Nonparametric Correlations

Correlations

			RACE_DISTANCE	EIPH_CASES
Spearman's rho	RACE_DISTANCE	Correlation Coefficient	1.000	-.327**
		Sig. (2-tailed)	.	.000
		N	445	445
	EIPH_CASES	Correlation Coefficient	-.327**	1.000
		Sig. (2-tailed)	.000	.
		N	445	445

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 7: Spearman's rho correlation test for average ambient temperature

Nonparametric Correlations

Correlations

			AVERAGE_AMBIENT_TEMPERATURE	EIPH_CASES
Spearman's rho	AVERAGE_AMBIENT_TEMPERATURE	Correlation Coefficient	1.000	.194**
		Sig. (2-tailed)	.	.000
		N	472	472
	EIPH_CASES	Correlation Coefficient	.194**	1.000
		Sig. (2-tailed)	.000	.
		N	472	472

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 8: Spearman's rho correlation test for relative humidity

Nonparametric Correlations

Correlations

			HUMIDITY	EIPH_CASES
Spearman's rho	RELATIVE_HUMIDITY	Correlation Coefficient	1.000	-.088
		Sig. (2-tailed)	.	.055
		N	472	472
	EIPH_CASES	Correlation Coefficient	-.088	1.000
		Sig. (2-tailed)	.055	.
		N	472	472

4.1 AGE

In accordance with routine practice for Thoroughbreds, the age of the horses in this study was calculated from January 1st of the year of their birth rather than from their actual date of birth. This means that the horse increases in age by 1 year on each subsequent January 1st, starting from its year of birth.

Figure 9 illustrated that the number of EIPH cases reported increased with age and most cases were reported in 7-year-old horses. However, the number of cases decreased after that age, with the lowest number recorded in 12-year-old horses. No cases were reported for the horses below 3 years old and above 12 years old from the record of September 2017 to August 2018. This was because the racehorses in STC were mainly imported and the horses were only allowed to start racing when they reached 3 years old. Normally, there is a limit to the number of years a racehorse can serve. According to the study by Gramm and Marksteiner (2010), the typical horse's peak racing age is 4.45 years, and the horses will have a decline in their racing ability past that age. Therefore, it was expected that old horses were lesser in STC. As a result, in this dataset, fewer cases were reported in older horses than in younger horses.

The Spearman's rho test showed that there was no significant association between the occurrence of EIPH and the age of the racehorses. Hence, the correlation coefficient was not significant. This result was in accordance with the findings by Speirs *et al.* (1982) and Lapointe *et al.* (1994). Conversely, some researchers found a positive association between age and the presence of EIPH (Newton and Wood, 2010; Weideman *et al.*, 2003). When looking into their studies, the result they obtained was

that the risk of EIPH increases when the horse is older (>3 years old) compared to younger horses, including yearlings and 2-year-olds. Thus, it was not against our finding since the correlation examined in the current study was for the horses that were 3 years old and older. Based on Figure 9, it was observed that the number of cases increased from 3 to 7 years of age. This supported previous research that found the risk of EIPH increases as the horse's age exceeds three years. However, the decline in cases due to the deletion of old horses was the most likely reason that caused the correlation to be non-significant in this study. In short, different age groups and ranges of the horses examined led to different conclusions for the correlation between age and the occurrence of EIPH.

Hinchcliff *et al.* (2010) proposed that the confounding effect of increased numbers of lifetime starts, which would be expected to be highly correlated with age in most horses, should be considered when doing the analysis. However, in this study, this confounding factor was unable to be taken into account since the horses were imported from foreign countries. It was expected that some of the horses had already undergone a considerable period of training and racing before being purchased. In conclusion, the research result on age and EIPH was largely affected by the sample group of the data examined in each study and needed to be interpreted carefully according to the practices at the location of the study.

Figure 9: Age of horse in relation to number of EIPH cases

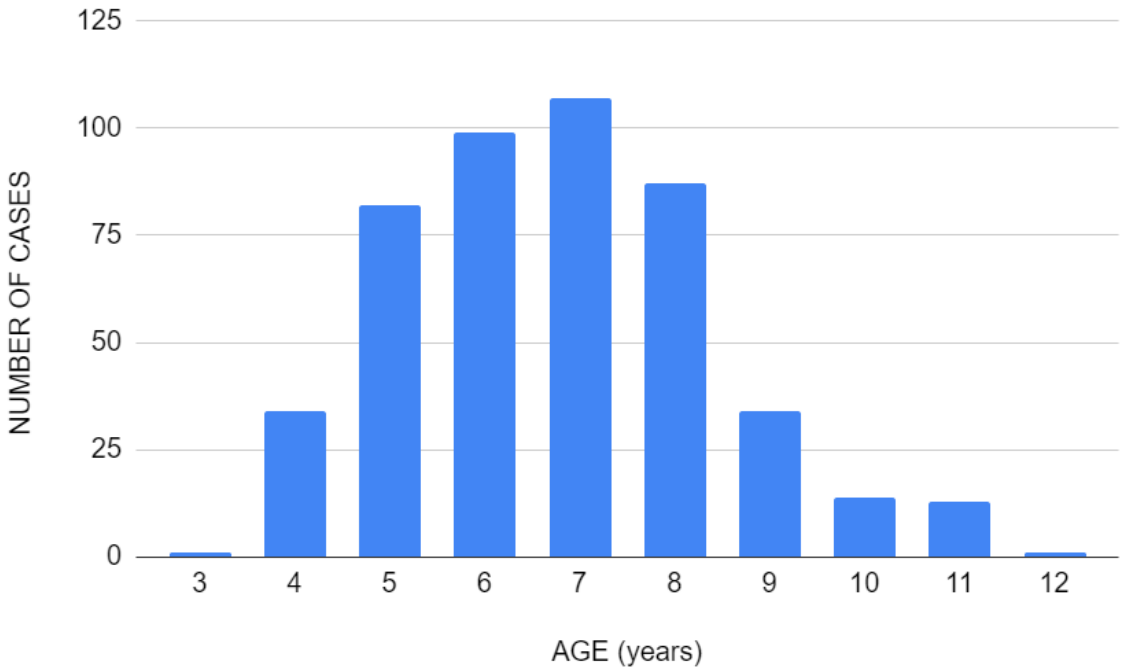
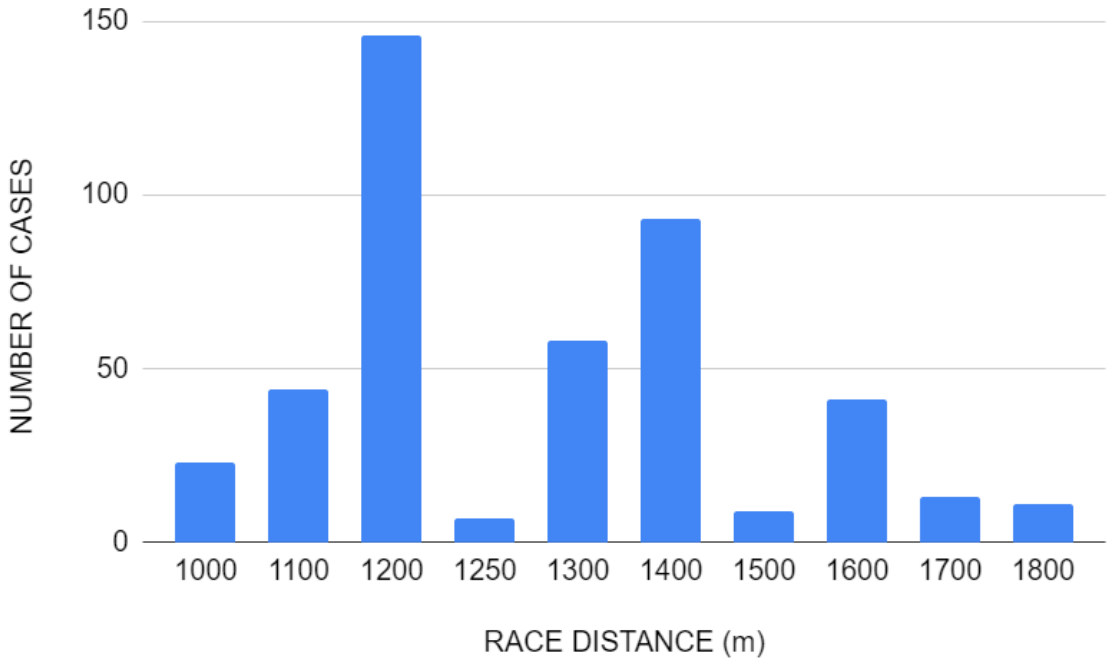


Figure 10: Race distance in relation to number of EIPH cases



4.2 RACE DISTANCE

The race distances competed in STC include 1000m, 1100m, 1200m, 1250m, 1300m, 1400m, 1500m, 1600m, 1700m and 1800m. As shown in Figure 10, the race distance of 1200m had the highest number of cases of EIPH reported, which was 146 cases. Race distances of 1250m and 1500m were newly introduced in STC this year (2022), which explains why the cases reported were less than 10 in these 2 distances despite the fact that the 1250 m race length was so close to the mode of this dataset (1200 m).

For the analysis of the association between the development of EIPH and race distance, a poor negative correlation with a coefficient of -0.327 was found ($p<0.05$). This means that when the race distance decreases, the incidence of EIPH increases, or vice versa. This finding was in accordance with the studies by Takahashi *et al.* (2001) and Poole and Eriskson (2016). They suggested that EIPH is more prevalent in shorter and higher intensity races due to the combination of higher positive pulmonary capillary intravascular pressure and negative alveolar pressure. The horses were being pushed to their maximum speed in a short period of time, thus the vessel might not be able to adapt to the fast change in pressure, leading to the injury of the capillaries' wall.

In contrast, some researchers did not find that race distance was associated with EIPH (Velie *et al.*, 2014; Weideman *et al.*, 2003). This might be due to the difference in the sample population examined compared to the current study. Velie *et al.* (2014) and Weideman *et al.* (2003) conducted studies on epistaxis in Thoroughbreds, but did not

include EIPH without epistaxis, whereas this study used data from horses with respiratory distress and epistaxis post-race.

In the context of the relationship between EIPH and race distance, the study by Costa and Thomassian (2006) found that bleeders showed a greater risk of recurrence in longer-distance races. They found a positive correlation between race distance and the recurrence of EIPH. This was opposite to the negative correlation found here but the current study did not include the race distance during the incidence of recurrence for analysis. In essence, the findings from the current retrospective examination might only be applicable to the first occurrence of the EIPH in Thoroughbred racehorses.

4.3 AVERAGE AMBIENT TEMPERATURE

The average ambient temperature was obtained by taking the average of the highest temperature and the lowest temperature recorded at the time from 12p.m. to 6p.m. on the day of the EIPH incidence. The temperature on the day of the first episode of EIPH for all 472 cases was used for analysis. In Figure 11, the average ambient temperature ranged from 25.5 to 34.5°C. Most cases were reported at 32.5°C (n=64).

The average ambient temperature was found to be significantly associated with EIPH ($p<0.05$) with a very poor positive correlation ($r=0.194$). The finding in this study was not consistent with the inverse association found in other literature (Crispe *et al.*, 2016; Lapointe *et al.*, 1994). According to the study by Hinchcliff *et al.* (2010), horses that race at an ambient temperature <20°C are 1.8-2.0 times more likely to develop occult EIPH than those racing at a temperature >20°C. However, it is important to note that the temperature range examined in these studies was different from the current retrospective analysis. For example, two of these studies had a temperature range of 13.5 to 37.7°C and -15 to 24°C respectively, whereas the temperature range in this study was relatively narrower and warmer (25.5 to 34.5°C).

Malaysia is a country located on the equator, the temperature and relative humidity are generally high all year round. A hot and humid climate was shown to impair the thermoregulation of horses during exercise (Hodgson *et al.*, 1994) and have a significantly higher heart rate when compared with exercising in hot but dry conditions (Geor *et al.*, 2010). A large proportion of the thermoregulation is done through sweating, but there is also >25% of the metabolic heat load during exercise dissipated through the

respiratory tract (Hodgson *et al.*, 1994). Hence, racehorses in the tropics are more difficult in regulating their body temperature effectively during racing. This might be relevant to the finding of a positive correlation between EIPH and the average ambient temperature in this study. Since a high level of effort was required during racing for effective thermoregulation and oxygen intake, it was possible to cause a more markedly increased pulmonary capillary pressure in a hot and humid environment. In spite of that, the relationship and the underlying mechanism between the high temperature and the development of EIPH warrant further investigation.

Figure 11: Average ambient temperature in relation to number of EIPH cases

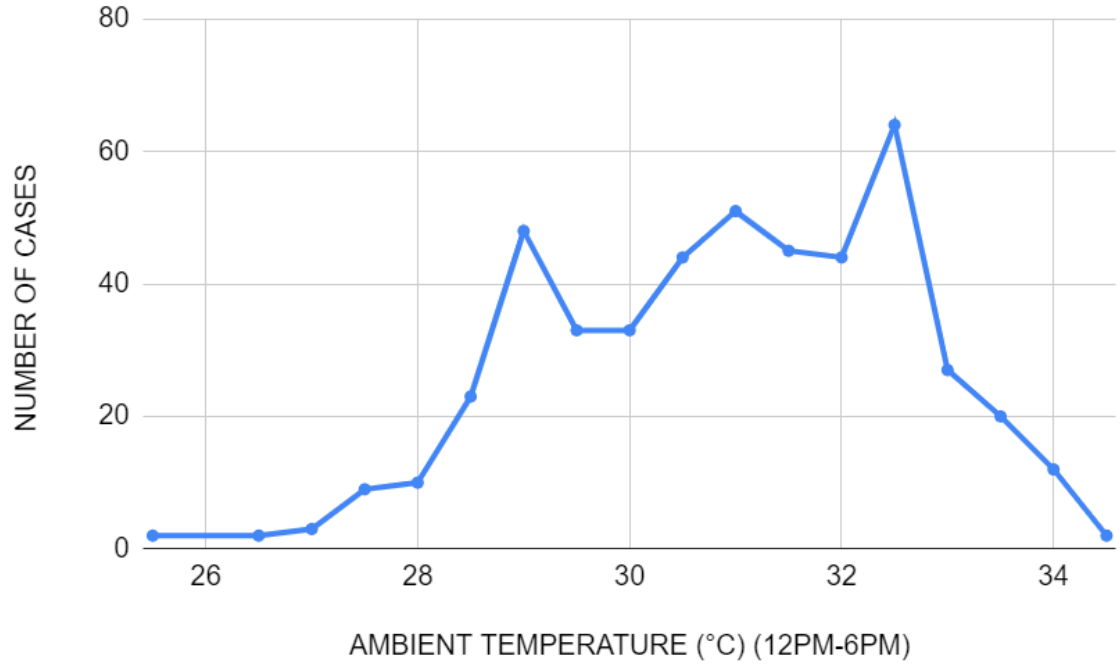
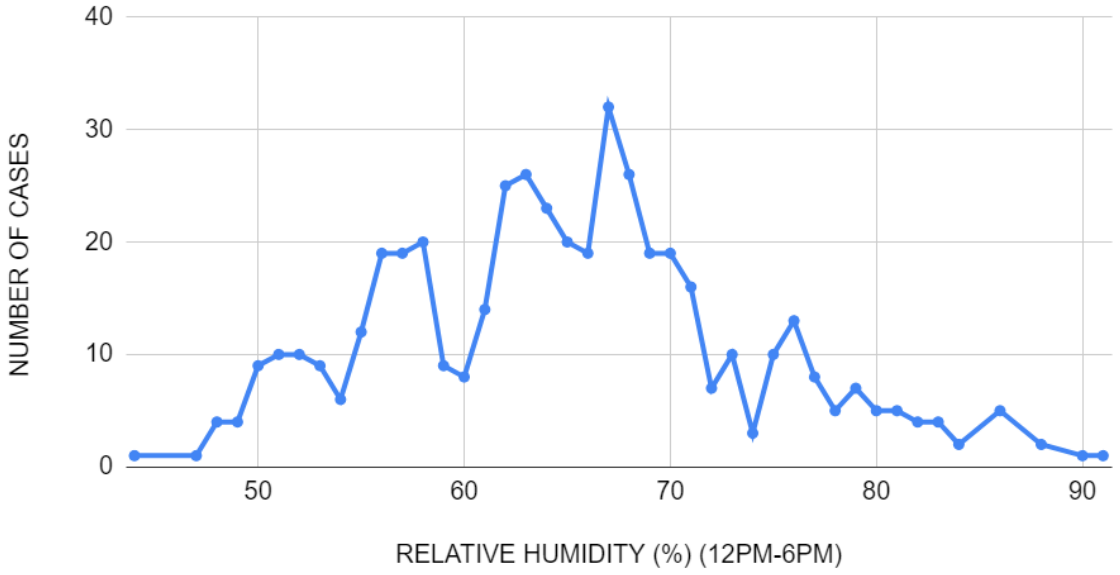


Figure 12: Relative humidity in relation to number of EIPH cases



4.4 RELATIVE HUMIDITY

The mean relative humidity from 12p.m. to 6p.m. was used for analysis. By looking at Figure 12, the distribution of the cases showed that many of the cases were reported when the relative humidity was between 55 and 70%. The mode of this data was at 67% relative humidity (n=32). According to a study in Malaysia, the average relative humidity in urban areas ranges from approximately 55 to 95% throughout the year (Abu Bakar and Gadi, 2016). Furthermore, most races were cancelled in extreme weather such as heavy rain, which can cause very high relative humidity. This caused more EIPH cases to be seen in the range of 55 to 70% relative humidity.

From Spearman's rho test, no significant association was identified between relative humidity and the occurrence of EIPH. Therefore, the correlation coefficient was not noteworthy. The relative humidity alone did not show an association with the EIPH and this finding was consistent with Lapointe *et al.* (1994). In comparison, Léguillette *et al.* (2016) reported that relative humidity was correlated with EIPH. However, their study focused on the EIPH in barrel racing, which is different from the flat racing discussed here. Thus, we can be convinced that the finding in the current retrospective examination was valid.

4.5 PERFORMANCE

For the performance of the racehorses, there is a rating system that categorizes them using the “points” they earned throughout their careers. When the horses get the first 3 places in a race, they will earn more points. The points for each horse will slowly accumulate from the races they win. The higher the points they own, the higher the rating they are. Therefore, the change in the rating of a horse can demonstrate the overall performance of the horse, whether it is performing well or not.

In this study, the performance of the horse with EIPH was assessed by comparing the change in its rating at its first episode of EIPH reported from September 2017 to August 2022 to its latest rating before it was completely withdrawn from racing. In the case of the horses that were deleted, the last rating recorded before the horse was deregistered was used to compare with the rating recorded in the first episode of EIPH. For the horses that were still actively competing, the latest rating during the period of data collection was retrieved for analysis. Some of the ratings at the point where the horses first recorded EIPH were unavailable because the horses might have bled during the barrier test. Ratings were only available in the system for the turf club's formal races. Therefore, only 448 cases were available for analysis.

From Table 1, more than half of the racehorses (56.03%) showed a decrease in their rating, while 23.21% maintained their rating and 20.76% showed an increase in their rating. This revealed that many of the horses with EIPH did not perform well in the races. For the horses that had their rating maintained, it might be due to the inconsistent

performance of the horse among the races or because the horse was deleted for some reason at the race it reported with EIPH.

For the finishing position of horses in the race where EIPH occurred, 442 cases have data available for analysis. Table 2 showed that among these horses, only 6.56% of them won the first 3 places in the race (n=29). More than 90% of the horses were unplaced in the race when EIPH occurred, which demonstrated how badly the EIPH affects the horses' race-day performance. This finding agreed with the previous studies (Crispe *et al.*, 2017; Hinchcliff *et al.*, 2005). In order to examine the relation between EIPH and poor performance, Lo Feudo *et al.* (2022) studied the fitness parameters, which include the speed at a heart rate of 200bpm and the speed and heart rate at which the blood lactate concentration reached 4mmol/L. However, no relationship was observed between EIPH and the aerobic or anaerobic capacity of the horse, indicating that EIPH may affect performance through a different mechanism that required further investigation.

Based on Table 3, among the 472 horses, 171 of them were having recurrent EIPH, which means that 36.23% of the horses had more than one episode of EIPH within the duration of the study. Moreover, the maximum frequency of EIPH recorded was 5 recurrences, reported in 2 racehorses. To be specific, 22.25% had 2 episodes of EIPH, 7.63% had 3 episodes, 4.24% reported 4 episodes, 1.69% had 5 episodes and 0.42% had 6 episodes of EIPH before they were deleted from racing. As the horses diagnosed with EIPH in this study were those experiencing epistaxis or respiratory distress, they were said to be with moderate to severe EIPH (≥grade 3). According to Sullivan *et al.* (2015), EIPH grade 4 was associated with impaired long-term race performance such as

career duration, earnings, starts, wins and placings. There was also evidence that showed that EIPH is progressive and associated with lung lesions such as regional fibrosis, which might be related to the high possibility of recurrence of EIPH (Hinchcliff *et al.*, 2015; Mckane *et al.*, 2010). The determination and comparison of the prevalence of EIPH in horses in different equestrian activities can be researched in the future, as it can be valuable information that enables a better understanding of the management of EIPH.

Table 4 showed that the number of horses being deleted in these 472 horses with EIPH was 286 horses in total over these 5 years, which constituted 60.59% of them. More than half of them were no longer racing and some might be deleted due to being chronic bleeders or having impaired racing performance. Besides that, some horses with EIPH were found to have other respiratory problems, such as laryngeal hemiplegia and respiratory infections. This can be examined in the future to see whether EIPH causes or correlates with other respiratory issues.

In short, the majority of the racehorses had a poor race-day performance and a drop in rating since their first episode of EIPH during the study period. Moreover, there were also considerable percentages of recurrence and deletion for the EIPH-positive horses. These results showed that EIPH has a financial impact on the racing industry due to its effect on racehorses' performance. Further research can be done to determine the reasons for premature deletion in turf clubs and identify the possibility of reducing the rate of deletion in the future.

Table 1: Number of horses and the change in rating

Change in rating	Number of horses	%
Increase	93	20.76
Maintain	104	23.21
Decrease	251	56.03
TOTAL	448	100

Table 2: Number of horses and the finishing position

Finishing position	Number of horses	%
1st	6	1.36
2nd	9	2.03
3rd	14	3.17
UNPLACED	413	93.44
TOTAL	442	100

Table 3: Number of horses and the frequency of EIPH

Frequency of EIPH	Number of horses	%
1	301	63.77
2	105	22.25
3	36	7.63
4	20	4.24
5	8	1.69
6	2	0.42
TOTAL	472	100

Table 4: Number of horses and the status

Status of horses	Number of horses	%
Deregistered	286	60.59
Active	186	39.41
TOTAL	472	100

4.6 OTHERS

4.6.1 SEX

No analysis was done on the correlation between the sex of horses and the occurrence of EIPH due to the fact that almost 90% of the horses (n=420) within the sample of 472 horses were geldings. The severely uneven distribution of the sexes of the racehorses in the STC makes this analysis impractical. In STC, most of the stallions will be castrated, or they will purchase castrated horses most of the time. Geldings were easier for management due to their predictability and less aggressiveness compared to stallions. Mares were also uncommon due to the turf club not practising any breeding programme and the presence of menstrual cycles in the mares complicates the management of the horses.

4.6.2 TRACK GOING

Another factor that was not analysed using the correlation test was the going of the track, which means the condition of the track during the race. The surface hardness of the track will be measured with a turf metre before each race starts. The going can be classified into several categories according to a standardised reference, which are good, yielding, soft and heavy in increasing order of softness. Among all the first episodes of EIPH cases reported, only 433 of the cases had information about the track going due to incomplete data in the system or the horse bleeding during the barrier test, where the track going was not tested. The majority of the track going, to be exact, 96.54% (n=418) of the track going recorded were in good condition, which was the most ideal track surface for racing. Hence, it can be concluded that the soft track surface does not contribute to the development of EIPH in racehorses. This finding was supported by other

literature (Hinchcliff *et al.,* 2010; Weideman *et al.*, 2003), where they did not find an association between track going and EIPH. Meanwhile, the research by Costa and Thomassian (2006) on the recurrence of EIPH identified track going as a significant risk factor for recurrent EIPH. This might be related to the lung lesions that predisposed the EIPH patients to recurrence and the underlying mechanism needs further investigation.

5.0 CONCLUSION

In conclusion, there was a significant correlation ($p<0.05$) between the occurrence of EIPH with the race distance ($r=-0.327$) and the average ambient temperature ($r=0.194$). However, no significant association was found between EIPH with age and relative humidity.

The risk factors identified in the current study can be considered when planning for the management of EIPH in Thoroughbred racehorses in turf clubs in the future. To reduce the frequency of the EIPH, the organisers can think about reducing short-distance races during hot weather. To be more specific, night racing and races >1400m can be considered in order to decrease the incidence of EIPH in the future.

Besides that, EIPH was shown to impair the performance of racehorses in this study based on the results of the change in rating, the finishing position and the percentage of recurrence and deletion from September 2017 to August 2022.

6.0 LIMITATIONS AND RECOMMENDATIONS

Limitations of this study included that there was incomplete data in the records such as the ratings and finishing positions of the EIPH-positive horses. Besides that, almost 90% of the horses in STC were geldings, so the correlation of the sex of the horse and the EIPH was unable to be performed.

In this study, a pretty high percentage of deletion was observed. Future study can be done to look into the reasons for premature deletion and the possibility of reducing it in the future. Furthermore, some of the EIPH-positive horses were found to have other respiratory issues like respiratory infection or laryngeal hemiplegia. Hence, we can examine the correlation of EIPH with other respiratory diseases and upper respiratory tract pathology in the future study.

7.0 REFERENCES

Abu Bakar, A. and Gadi, M.B. (2016). Urban Outdoor Thermal Comfort of The Hot-humid Region. MATEC Web of Conferences, 66, 00084.

Birks, E.K., Mathieu-Costello, O., Fu, Z., Tyler, W.S. and West, J.B. (1997). Very high pressures are required to cause stress failure of pulmonary capillaries in Thoroughbred racehorses. Journal of Applied Physiology, 82(5), 1584–1592.

Birks, E.K., Shuler, K.M., Soma, L.R., Martin, B.B., Marconato, L., Piero, F., Teleis, D.C., Schar, D., Hessinger, A. E. and Uboh, C. E. (2002): EIPH: Postrace Endoscopic Evaluation of Standardbreds and Thoroughbreds. Equine Veterinary Journal, 34(S34), 375–378.

Costa, M.F.M. and Thomassian, A. (2006). Evaluation of race distance, track surface and season of the year on exercise-induced pulmonary haemorrhage in flat racing Thoroughbreds in Brazil. Equine Veterinary Journal, 38(S36), 487–489.

Crispe, E.J., Lester, G.D., Robertson, I.D. and Secombe, C.J. (2016). Bar shoes and ambient temperature are risk factors for exercise-induced pulmonary haemorrhage in Thoroughbred racehorses. Equine Veterinary Journal, 48(4), 438–441.

Crispe, E.J., Lester, G.D., Secombe, C.J. and Perera, D.I. (2017). The association between exercise-induced pulmonary haemorrhage and race-day performance in Thoroughbred racehorses. Equine Veterinary Journal, 49(5), 584–589.

Davis, E. (2018). Disorders of the Respiratory System. In Equine Internal Medicine (pp.313–386). Elsevier.

Erickson, B.K., Erickson, H.H. and Coffman, J.R. (2010). Pulmonary artery, aortic and oesophageal pressure changes during high intensity treadmill exercise in the horse: a possible relation to exercise-induced pulmonary haemorrhage. Equine Veterinary Journal, 22(S9), 47–52.

Geor, R.J., McCutcheon, L.J., Ecker, G.L. and Lindinger, M.I. (2010). Thermal and cardiorespiratory responses of horses to submaximal exercise under hot and humid conditions. Equine Veterinary Journal, 27(S20), 125–132.

Gramm, M. and Marksteiner, R. (2010). The effect of age on thoroughbred racing performance. Journal of Equine Science, 21(4), 73–78.

Hodgson, D.R., Davis, R.E. and McConaghy, F.F. (1994). Thermoregulation in the horse in response to exercise. British Veterinary Journal, 150(3), 219–235.

Hinchcliff, K.W., Jackson, M.A., Morley, P.S., Brown, J.A., Dredge, A.F., O'Callaghan, P.A., McCaffrey, J.P., Slocombe, R.F. and Clarke, A.F. (2005). Association between exercise-induced pulmonary hemorrhage and performance in Thoroughbred racehorses. Journal of the American Veterinary Medical Association, 227(5), 768–774.

Hinchcliff, K.W., Morley, P.S., Jackson, M.A., Brown, J.A., Dredge, A.F., O'Callaghan, P.A., McCaffrey, J.P., Slocombe, R.F. and clarke, A.F. (2010). Risk factors for exercise-induced pulmonary haemorrhage in Thoroughbred racehorses. Equine Veterinary Journal, 42, 228–234.

Hinchcliff, K.W., Couetil, L.L., Knight, P.K., Morley, P.S., Robinson, N.E., Sweeney, C.R. and van Erck, E. (2015). Exercise Induced Pulmonary Hemorrhage in Horses: American College of Veterinary Internal Medicine Consensus Statement.

Lapointe, J.M., Vrins, A. and McCarvill, E. (1994). A survey of exercise-induced pulmonary haemorrhage in Quebec Standardbred racehorses. Equine Veterinary Journal, 26(6), 482–485.

Léguillette, R., Steinmann, M., Bond, S.L. and Stanton, B. (2016). Tracheobronchoscopic Assessment of Exercise-Induced Pulmonary Hemorrhage and Airway Inflammation in Barrel Racing Horses. Journal of Veterinary Internal Medicine, 30(4), 1327–1332.

Lopez Sanchez, C.M., Kogan, C., Gold, J.R., Sellon, D.C. and Bayly, W.M. (2020). Relationship between tracheobronchoscopic score and bronchoalveolar lavage red blood cell numbers in the diagnosis of exercise- induced pulmonary hemorrhage in horses. Journal of Veterinary Internal Medicine, 34(1), 322–329.

Lo Feudo, C.M., Stucchi, L., Stancari, G., Alberti, E., Conturba, B., Zucca, E. and Ferrucci, F. (2022). Associations between Exercise-Induced Pulmonary Hemorrhage (EIPH) and Fitness Parameters Measured by Incremental Treadmill Test in Standardbred Racehorses. Animals, 12(4), 449.

Mckane, S.A. and Slocombe, R.F. (2010). Alveolar fibrosis and changes in equine lung morphometry in response to intrapulmonary blood. Equine Veterinary Journal, 34(S34), 451–458.

Newton, J.R., Rogers, K., Marlin, D.J., Wood, J.L.N. and Williams, R.B. (2010). Risk factors for epistaxis on British racecourses: evidence for locomotory impact-induced trauma contributing to the aetiology of exercise-induced pulmonary haemorrhage. Equine Veterinary Journal, 37(5), 402–411.

Newton, J.R. and Wood, J.L.N. (2010). Evidence of an association between inflammatory airway disease and EIPH in young Thoroughbreds during training. Equine Veterinary Journal, 34(S34), 417–424.

Pascoe, J.R., Ferraro, G.L., Cannon, J.H., Arthur, R.M. and Wheat, J.D. (1981). Exercise-induced pulmonary hemorrhage in racing thoroughbreds: a preliminary study. American Journal of Veterinary Research, 42(5), 703–707.

Poole, D. and Erickson, H. (2016). Exercise-induced pulmonary hemorrhage: where are we now? Veterinary Medicine: Research and Reports, Volume 7, 133–148.

Speirs, V.C., Veenendaal, J.C., Harrison, I.W., Smyth, G.B. Anderson, G.A., Wilson, D.V. and Gilbo, B. (1982). Pulmonary haemorrhage in standardbred horses after racing. Australian Veterinary Journal, 59(2), 38–40.

Schroter, R.C., Marlin, D.J. and Denny, E. (1998). Exercise-induced pulmonary haemorrhage (EIPH) in horses results from locomotory impact induced trauma - a novel, unifying concept. Equine Veterinary Journal, 30(3), 186–192.

Schroter, R.C., Leeming, A., Denny, E., Bharath, A. and Marlin, D.J. (2010). Modelling impact-initiated wave transmission through lung parenchyma in relation to the aetiology of exercise-induced pulmonary haemorrhage. Equine Veterinary Journal, 31(S30), 34–38.

Sullivan, S.L. Anderson, G.A., Morley, P.S. and Hinchcliff, K.W. (2015). Prospective study of the association between exercise-induced pulmonary haemorrhage and long-term performance in Thoroughbred racehorses. Equine Veterinary Journal, 47(3), 350–357.

Sullivan, S. and Hinchcliff, K. (2015). Update on exercise - Induced pulmonary hemorrhage. In Veterinary Clinics of North America - Equine Practice (Vol. 31, Issue 1, pp. 187–198). W.B. Saunders.

Takahashi, T., Hiraga, A., Ohmura, H., Kai, M. and Jones, J.H. (2001). Frequency of and risk factors for epistaxis associated with exercise-induced pulmonary hemorrhage in horses: 251,609 race starts (1992–1997). Journal of the American Veterinary Medical Association, 218(9), 1462–1464.

Toutain, P.L. (2010). Veterinary Medicines and Competition Animals: The Question of Medication Versus Doping Control (pp. 315–339).

Velie, B.D., Raadsma, H.W., Wade, C.M., Knight, P.K. and Hamilton, N.A. (2014). Heritability of epistaxis in the Australian Thoroughbred racehorse population. The Veterinary Journal, 202(2), 274–278.

West, J.B., Mathieu-Costello, O., Jones, J.H., Birks, E.K., Logemann, R.B., Pascoe, J.R. and Tyler, W.S. (1993). Stress failure of pulmonary capillaries in racehorses with exercise-induced pulmonary hemorrhage. Journal of Applied Physiology, 75(3), 1097–1109.

Weideman, H., Schoeman, S.J., Jordaan, G.F. and Kidd, M. (2003). Epistaxis related to exercise-induced pulmonary haemorrhage in South African Thoroughbreds. Journal of the South African Veterinary Association, 74(4), 127–131.