Does the start of flat races influence racehorse race performance?

Isobel Wells[1], Hayley Randle[2] and Jane M. Williams[1]*

[1]Hartpury University

Gloucester

United Kingdom

GL19 3BE

[2] Charles Sturt University

Wagga Wagga

Australia

NSW, 2678

*Corresponding author: jane.williams@hartpury.ac.uk

00 44 1452 706240

ABSTRACT

It is in the horse racing industry's interest to understand all factors that impact performance to maintain the integrity of the sport. There is some evidence that the start of flat races can affect racehorse performance. However, limited research exists on the explicit effect that waiting at the start and inside starting stalls (also known as starting gates or barriers) has on racehorse finishing position. This study investigated how temporal, behaviour and loading related factors associated with the period before the start of the race influences racehorse performance. A cross-sectional design evaluated performance of 546 horses across eight flat race days at Chelmsford City Racecourse in November and December 2020, using televised racing coverage. Time horses spent inside starting stalls, the use of loading aids and jockey behaviours were recorded. Notational analysis was used to determine how much horses sweat and their behaviour before, during and after loading. Behaviour was categorised using an ethogram adapted from previous published research recording conflict behaviour in horses. Horses that spent under 50 seconds inside starting stalls were more likely to win (p<0.05) or finish in the top three (p<0.01). Those showing moderate adverse behaviour before loading (p<0.01) and no adverse behaviour inside stalls (p<0.05) were more likely to win and place first to third, respectively, although behaviour during loading had no significant effect. Horses sweating to the point of foaming (p<0.01) and requiring specialist loaders (p<0.05) were more likely to win, although the use of other loading aids did not significantly affect performance. Jockeys that pushed their bodyweight forwards in the saddle during loading were significantly more likely to place first to fourth (p<0.05). A horse's chance of placing first to third was reduced by 15% for every increase in drawn order (p<0.01; CI:0.77-0.96) and by 59% when the horse spent over 50 seconds inside stalls (p<0.05; CI:0.19-0.92). A horse's likelihood of placing decreased by 13% for every year of age (p<0.05; CI:0.78-0.97) and by a further 17% for each additional horse in the field (p<0.001; CI:0.00-0.83). Racehorses showing adverse behaviour inside stalls were 52% less likely to place (p<0.05; CI:0.00-0.48). This research demonstrates that the start of flat races can influence performance, highlighting the importance of warm-up protocols and starting gate training to optimise performance. With further longitudinal research, these findings could support adjustments to the rules of racing regarding the start to improve and maintain the integrity of horseracing in the UK.

Keywords: horseracing, starting stalls, behaviour, thoroughbred, loading aids, ethogram

1.0 INTRODUCTION

Horseracing has a long history in the United Kingdom (UK), with records suggesting racing has been popular since the 10th Century and it remains the second largest spectator sport to date (Great British Racing, 2022). Across the UK's 60 racecourses, 25 host flat racing, with nearly 6,500 flat races run annually at almost 900 meetings. To begin races fairly and maintain racing integrity so that no horse has an unfair advantage, flat races are started by simultaneously releasing horses from starting stalls (alternatively known as starting gates or barriers) (Figure 1) (BHA, 2021a). The start of races has long been recognised anecdotally and in research to influence racehorse performance in flat racing (Burnley and Jones, 2007; McBride and Mills, 2012; Cully *et al*., 2018), particularly in shorter distance flat races ('sprints' of five (1000m) and six (1200m) furlongs) where the consequence of a 'bad start' is amplified (Legg *et al.*, 2020). A bad start, or 'break', is defined as horses reacting slowly to stalls opening and consequently starting behind other runners. However, to the authors' knowledge, limited studies have explicitly evaluated the effect that waiting at the start and inside stalls has on racehorse finishing position.

Figure 1: Starting stalls, also known as starting gates or barriers, are used to release horses simultaneously at the beginning of the race for a fair start. (Photo: Author IW's own)

Before the race, horses are paraded and then canter to the designated race start where a team of qualified handlers and a designated race starter are responsible for loading them into the starting stalls (Figure 2) to enable the race to commence at its designated time. Protocols dictate the loading process and several ancillary methods are available to facilitate the successful and safe loading of racehorses into the stalls (Ahern, 2020) (Table 1). The sequence of loading (and therefore the time a horse is required to stand inside stalls) is dictated by randomly-assigned draw numbers, which are allocated before the race (BHA, 2021b). Blindfolded horses, or those blindfolded previously, load first followed by horses with odd draw numbers and finally evenly-drawn horses (BHA, 2021b). However, loading sequence is often altered to increase speed and efficiency of loading and reduce time horses spend inside stalls (BHA, 2021b). If a horse refuses to load after several attempts (although there is no standardised number) and delays the start, they can also be withdrawn from the race by the starter (McBride and Mills, 2012; BHA, 2021b; BHA, 2021c). Problematic behaviours that put the health and welfare of horses, jockeys and stall handlers at risk can also result in horses being withdrawn from the race. Horse excitement or anticipation increases the risk of injury, with injuries sustained in or around the gates accounting for 35.1% (Waller *et al*., 2000) to 41% (Ryan *et al*., 2020) of all flat jockey injuries. Whilst the influence of jockeys during races has been investigated (Jackman *et al*., 2015), research detailing the potential influence of jockeys and handlers on racehorse behaviour pre-race is limited.

Figure 2: Horses are loaded into starting stalls prior to racing by a team of qualified handlers. (Photo: Author IW's own).

Table 1: Ancillary methods (loading aids) used to facilitate the successful and safe loading of racehorses into starting stalls (also known as starting gates or barriers) (Ahern, 2020).

Loading Aid	Use
Straps	Used by handlers to apply physical pressure to the horse's hindquarters to encourage horse into stalls.
Blindfold	Reduce visible stimulation and dissociate the horse from its environment.
Blanket	Prevent the side of the stalls coming into contact with the horse's sides, reducing the number of environmental stimuli impacting the horse.
Specialist loader	A person other than the standard stall handlers that handles the horse around starting stalls, often equine behaviourists.

The behaviour of racehorses during loading and within the starting stalls before the race can be influential to individual and neighbouring racehorse performance (Hutson and Haskell, 1997). Inside the stalls, racehorse heart rates (HR) can peak to an average of 171.4bpm, an increase of 57% from HRs recorded pre-loading, around the starting gate by Mukai *et al*. (2007). This could be due to anticipation, excitement or stress (Waller *et al.*, 2000). The inverted-U hypothesis models the association between arousal and performance, suggesting that both too little and too much arousal can be detrimental to performance (Gould and Udry, 1994). Splenic contraction, mediated by epinephrine amongst other catecholamines (Bakovic *et al*., 2013; Vazzana *et al.*, 2014), increases haematocrit and, subsequently, aerobic capacity. However, an excessively high HR from over-excitement may hinder performance. Epinephrine released in response to stress can cause sweating before racing (McConaghy *et al*., 1995), as well as environmental factors such as temperature; sweating is suggested to be detrimental to performance due to associated electrolyte deficiencies (Lindinger, 2008; McGowan, 2008). Latherin, a surfactant protein component of equine sweat, can make sweat appear white and 'foamy' when horses sweat profusely causing greater electrolyte losses that could have a greater effect on performance (McDonald *et al*., 2009; Mitchell, 2018). Anecdotally sweating in racehorses during race preliminaries is often associated with temperament and can be considered to represent under- or over-arousal before races. Despite this, currently, research evaluating associations between arousal and behaviour and physiological parameters of performance is limited in racehorses.

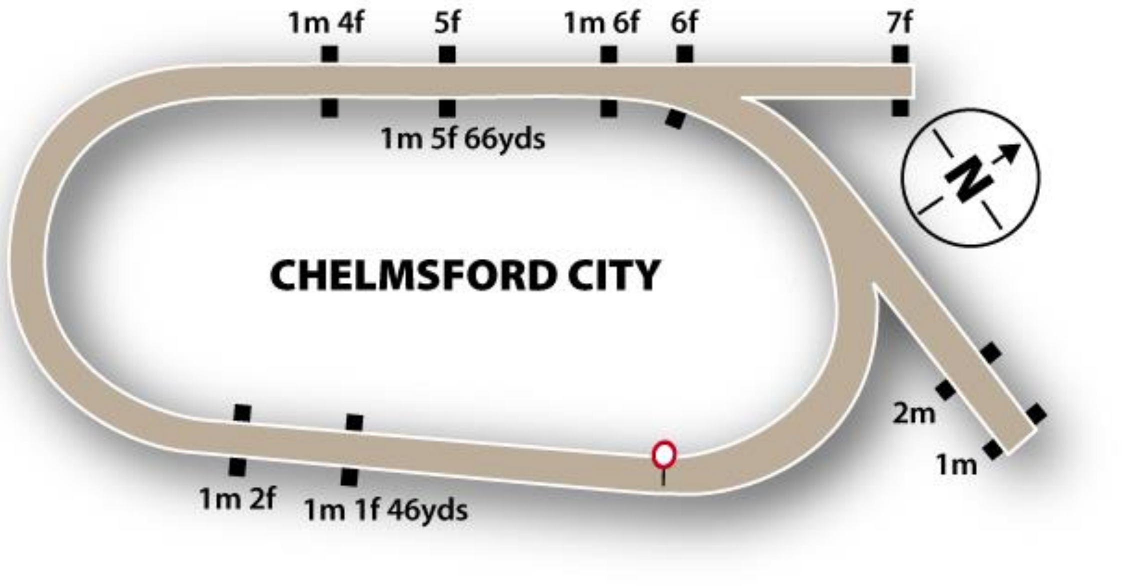
The present study aimed to explore how time spent in and around starting stalls affected horses' race performance (defined by finishing position) in flat racing, by evaluating the influence of time spent inside starting stalls, racehorse behaviour, the use of loading aids, horse sweating and jockey actions at the start on finishing order.

2.0 METHODOLOGY

2.1. Data Collection

A quantitative, cross-sectional approach (Cheetham *et al*., 2010) explored the effect of time spent in and around starting stalls on finishing position of racehorses in flat races at Chelmsford City racecourse (Figure 3). Due to the Covid-19 pandemic and resulting restrictions preventing access to racecourses, televised coverage from Racing TV was used to observe horses around and inside starting stalls. Each meeting at Chelmsford City racecourse was recorded on a Virgin Media TiVo box for review, and a convenience sample of all horses (n=594) racing between the 5th of November and the 10th of December 2020 across eight meetings were used. Three further meetings were omitted after two recording errors and one cancellation due to poor weather. Data from races (n=65) were collated in a Microsoft Excel spreadsheet (Microsoft Office 2020, New Mexico, USA). To align with General Data Protection Regulation guidelines, all data were anonymised and stored in a secure OneDrive folder. Ethical approval was obtained from the Hartpury University Ethics Committee (ETHICS2020-14-LR).

Figure 3: Chelmsford City Racecourse is a left-handed track with an all-weather polytrack surface, sweeping bends, two two-furlong straights and chutes for seven furlong, one and two mile starts. It is just over a mile in circumference, and is located in Essex in the east of England, UK (51.842°N,0.512°E). It is the newest racecourse in England as of 2022, having opened in 2008. (Photo: At The Races)



Following a pilot study to assess Racing TV coverage, inclusion criteria for races were set to ensure selected races included a minimum of 30s of stalls footage showing at least four horses loading. Races with insufficient coverage (n=7) were excluded. For a horse to be included it had to be in the cinematographic shot for a minimum of 10s at the start and inside stalls. Horses withdrawn due to excessive misbehaviour or attempted escape from stalls were removed from the dataset (n=2), along with horses who did not finish the race due to injury (n=1). Consequently, 546 horses and 58 races were included in the sample, although this included repeated horses: 45 horses ran twice and five ran three times across the eight race days.

Once footage had been collected, the time each horse spent in the stall (s) was calculated by subtracting the timestamp at which both doors of the stalls closed behind the horse from the time the race started. Horses not shown loading were recorded as not visible.

Behaviour of every horse was characterised and measured using notational analysis (Hughes, 2004) and included behaviour before loading (no, moderate, excessive adverse behaviour), during loading (willing, unwilling) and inside stalls (no, moderate, excessive adverse behaviour). Behaviour was defined and recorded using two ethograms (Table 2 and 3) adapted from previous research into stress, discomfort, frustration or conflict behaviours shown by horses (Kaiser *et al*., 2006; von Borstel *et al*., 2009; von Borstel and Kiel, 2012; Pierard *et al*., 2019). Research studying horse behaviour when loading into trailers (Yngvesson *et al*., 2016) and specific racehorse behaviours observed in the pilot study were also incorporated.

Table 2: Ethogram to measure adverse behaviour before loading and when waiting inside stalls (McGreevy et al., 2005; Kaiser et al., 2006; Visser et al., 2009; von Borstel et al., 2009; von Borstel and Keil, 2012; Munsters et al., 2013; Pierard et al., 2019).

	Behavioural marker	Definition
No adverse behaviour	Normal head carriage	Holds head in a normal carriage (between the withers and abdominal line)
	No lip movement	Shows few (<2) or no lip movements
	Ears pointing forwards	Ears are in a relaxed and forwards position, possibly flicking backwards and forwards
Moderate adverse behaviour	Head toss	Moves head in a fast forward-upward motion
	Ears pinned back	Lays its ears back for a prolonged (>5s) bout
	Head raised	Holds head above normal carriage (above withers), possibly with extension of the neck
	Head down	Holds head below normal carriage (between the abdominal line and carpus), possibly with extension of the neck
	Head shake	Moves head in a slower, rhythmic flipping motion
	Head turn	Moves head to the side independent of the jockey
	Lip movements	Movement of the tongue in and out of the mouth

	Defecation	Expelling of faeces
	Change of pace	Tries to stop moving forward or breaks into bouts of trot/jog
	Bouts backing up	Moves backwards instead of forward
	Crabbing	Moves in a sideward-forward motion rather than in a straight line so that hind legs do not track up with front legs
	Tail-swishing	Fast, lateral or vertical tail movement
	Pawing ground	Lifts a forelimb vertically and digs at ground
Excessive adverse behaviour	Attempted bucks	Jumps in a forward-upwards motion whilst arching back, often with ears laid back
	Shying	Reacts suddenly with a movement that involves the horse swerving its fore-quarters
	Striking	Moves one or both forelimbs quickly, possibly but not necessarily directed at another horse or human
	Kicking	Moves one or both hindlimbs quickly, possibly but not necessarily directed at another horse or human
	Rearing	Lifts both forelimbs off the ground simultaneously without moving forwards
	Bucking	Raises both hindlimbs off the ground simultaneously so that the pelvis is higher than the withers

Table 3: Ethogram to measure willingness to go forward (Yngvesson et al., 2016; Dyson et al., 2018)

	Behavioural marker	**Definition**
Willing	Forward movement	Moves forwards towards stall
Unwilling	Backward movement	Moves backwards away from stall
	Sideways movement	Moves sideways away from stall
	Plant feet	Stands stationary in front of stall for >3s
	Kicking	Moves one or two legs quickly and with force
	Forceful evasion	Jumps suddenly or throws themself towards or away from stall
	Rearing	Lifts both forelimbs off the ground simultaneously without moving forwards

Focal sampling (Bosholn and Anciaes, 2018) was used with the ethograms to record behaviour of each horse at five-second intervals from the first horse arriving behind stalls after cantering to the start to the beginning of the race. One consistent observer familiar with the criteria and with underpinning knowledge and understanding of horseracing was used to ensure behaviour was measured equally across races (Author IW). The number of times behavioural markers were observed for each horse was recorded and threshold levels were set to consistently rate behaviour (Dyson, 2018). When measuring behaviour before loading, three different adverse behaviours were required to consider a horse as showing ‘moderate adverse behaviour’, and six or more different adverse behaviours were required for a horse to be classed as showing ‘excessive adverse behaviour’. A scoring system was devised after reviewal of footage to categorise behaviour more accurately, with ‘excessive’ behaviours (attempted bucking, shying, striking, kicking, rearing and bucking) being worth twice the score (2) of milder behaviours (1) due to increased risk of injury (von Borstel *et al.*, 2009). Exhibition of one ‘unwilling’ behaviour was required for a horse to be classified as unwilling to go into stalls. Once loaded, horses had to exhibit one ‘moderate’ adverse behaviour to be classified as demonstrating ‘moderate adverse behaviour’, whereas the presence of one ‘excessive’ adverse behaviour was required to be classified as exhibiting ‘excessive adverse behaviour’ inside stalls. The observation time available to record each horse’s behaviour was recorded. Horses out of shot at the time of sampling were recorded as not visible.

Notational analysis (Hughes and Franks, 2004; Marlin and Williams, 2020) was used to measure how much horses sweat at the start (not sweating, sweating, foaming). Loading aids used (blindfold, blanket, straps, specialist loaders) and the number of stall handlers required (leading, pushing or otherwise assisting) were noted for every horse. Jockey behaviours before (removing feet from stirrups, standing in stirrups, dismounting) and during loading (pushing forwards, kicking, whipping, dismounting) were recorded. Field size, loading order, drawn order, race distance and ground going (‘track condition’ in the USA or ‘track rating’ in Australia) for each race and each horse’s age, official rating (or ‘handicap mark’, which is given to a horse after it has won a race or placed within the top six three times and is used to determine their handicap) and sex was determined using At The Races (www.attheraces.com) and Racing Post (www.racingpost.com) websites. Environmental conditions for each race were recorded (www.worldweatheronline.com). Public data from the Racing Post were used to determine finishing order for each race.

2.2 Descriptive Analysis

Data were described using descriptive and frequency analyses (Thompson, 2009). Frequency analysis of variables with nominal data was utilised to profile horses and races within variables and in further statistical analysis. Variables with continuous data were described using descriptive analysis to generate means, standard deviations (SD), medians and interquartile ranges (IQR) (Manikandan, 2011). Means and SD were presented as mean±SD, and medians and IQR were presented as median±IQR.

2.3 *Statistical Analysis*

SPSS (IBM, version 26) was used for statistical analyses and significance was set at $p<0.05$ (Schober *et al*., 2018a). Non-parametric tests for difference (Mann Whitney (MW) for variables with two groups or Kruskal-Wallis (KW) with a MW post-hoc for variables with three groups) were run for variables with nominal data (Nachar, 2008). This determined whether differences existed between horses that won and horses that did not and the independent variables tested. For variables with continuous data, data were tested for normality using a Kolmogorov-Smirnov test (Yap and Sim, 2011). As data met non-parametric assumptions, a series of Spearman's Rho (SR) correlations (Schober *et al*., 2018b) tested if relationships existed between independent variables and race performance. The strength of correlation coefficients (r_s value) were interpreted as negligible (0.00-0.29), low (0.30-0.49), moderate (0.50-0.69), high (0.70-0.89) or very high (0.90-1.00) (Mukaka, 2012). General linear models (GLMs) were used to identify significant interaction between variables (Hayes *et al*., 2012). These were interpreted using estimated marginal means for interaction involving two variables and interaction graphs for three or more variables.

Binary logistic regression (BLR) (Sperandei, 2014; Marlin and Williams, 2020) determined if independent variables collated related to performance. Univariable analysis informed multivariable model building using the dichotomous variables win/no-win (Model A) and placed 1st-3rd/did not place 1st-3rd (Model B). For variables to be eligible for multivariate models, a significance level of $p<0.10$ was required during univariate regression (Smith *et al*., 2020). In Model A, five horse-level variables were included in the model: drawn order, sex, spending over or under 50s inside stalls, loading with a specialist loader and extent of sweating. In Model B, seven horse-level variables were included: drawn order, age, sex, time in stall, spending over or under 50s inside stalls, behaviour before loading and behaviour in stalls (redefined as binary: adverse or no adverse behaviour). Field size was included in both models as a race-level variable. A backward stepwise process was used to refine models, which retained variables if Likelihood ratio significance was $p<0.05$ (Tanner *et al*., 2013). Omnibus tests at each step of model building identified how variables affected model fit and if they should be retained ($p<0.05$). Hosmer-Lemeshow goodness of fit tests assessed model fit ($p>0.05$) (Tamura *et al*., 2018) and receiver-operating characteristic (ROC) curve analysis evaluated predictive ability of the models (Brown and Davis, 2006).

3.0 RESULTS

3.1 Frequency and descriptive analysis of data

A total of 546 horses met inclusion criteria and were used in analyses. These had an average age of 4.0±2.0 years and a median official rating of 60.0±24.0. Geldings made up the largest proportion of the sample (48.0%, n=262), followed by fillies (33.7%, n=184), entire males (stallions and colts combined) (13.0%, n=71) and mares (5.3%, n=29).

Average field size was 9.0±2.0 horses and average race distance was 8.0±2.0 furlongs. Median temperature, humidity, rainfall and windspeed was 6.0±2.0°C, 89.0±14.0%, 0.0±0.4mm and 13.0±9.5km, respectively. The going was always ‘standard’, the optimal conditions for all-weather tracks, meaning there was never too much nor too little moisture in the ground.

3.1.1 Loading of racehorses into starting stalls

The median time horses spent inside stalls was 31.0±45.0s, with an average of 3.0±0.5 handlers assisting each horse during loading. At least one loading aid was required by 24.5% (n=134/441) of horses observed entering stalls or wearing a loading aid at the start. Straps were used most commonly (23.6%, n=100/424) with a lower frequency of other loading aids recorded (blindfolds: 6.8%, n=37/546; blankets: 2.4%, n=13/546; specialist loaders: 2.1%, n=9/426). Most horses (76.2%, n=329/432) were willing to enter stalls, with 23.8% (n=103/432) resisting loading. Before loading, most horses exhibited no adverse behaviour (68.8%, n=358/520), approximately a quarter exhibited moderate adverse behaviour (26.7%, n=139/520) and few demonstrated excessive adverse behaviour (4.4%, n=23/520). Most horses displayed no adverse behaviour once loaded (78.9%, n=431/546), with 16.8% displaying moderate (n=92/546) and 4.2% displaying excessive (n=23/546) adverse behaviour. Most horses (84.4%, n=461/546) did not sweat at the start: 10.8% of horses were damp with sweat (n=59/546) and 4.8% (n=26/546) had observable foam on their neck, flank, between their hindlegs and/or under tack.

3.1.2 Jockey influence on racehorses at the start

Based on footage, 3.8% (n=21/546) of jockeys removed their feet from the stirrups, 5.9% (n=32/546) stood in their stirrups and 3.1% (n=17/546) dismounted before loading. When entering stalls, 5.0% of jockeys (n=22/439) visibly pushed their bodyweight forwards in the saddle, 3.2% (n=14/442) kicked and 2.7% (n=12/442) used the whip to encourage loading. Only 1.8% (n=10/546) of horses entered the stalls without the jockey mounted.

3.2. Relationship between time in stalls and performance

When tested using Spearman’s Rho, significant correlations were found between the time horses were inside starting stalls and finishing position (r=0.135; p=0.006) and drawn order and finishing position (r=0.139; p=0.001), although coefficients were too small to be meaningful. However, time spent in the stalls influenced racehorse performance. Mann-Whitney U tests found that horses that spent 49s or less inside stalls were more likely to win (>50s mean ranked difference, MRD reduced by 17.18; U=17276.00; p=0.015) and place (>50s MRD reduced by 29.47; U=17013.50; p=0.005) than horses waiting inside for 50s or more. Other thresholds were tested at 10s intervals from 10-150s, but differences between winning or placing horses and others were most significant at 50s. Spending a longer time in stalls was associated with earlier loading (F(1,108)=36.20; p=0.0002) and increased field size (F(1,108)=24.30; p=0.0003).

3.3. Effect of horse behaviour and loading aids on performance

3.3.1 Behaviour before loading

Significant differences in behaviour before loading were found between horses placing first, second or third or lower (H(2)=7.66; p=0.022). Horses exhibiting moderate adverse behaviour before loading were more likely to win than those showing no adverse behaviour (NA MRD reduced by 29.48; U=21848.00; p=0.005). More adverse behaviour before loading was associated with sweating, but not foaming (F(1,148)=3.78; p=0.025) when tested with GLMs.

3.3.2 Willingness to load and use of loading aids

Willingness to load had no significant effect on whether horses won (U=16659.00; p=0.639) or placed (U=16429.00; p=0.567). Using a blindfold, blanket or straps when loading had no significant effect on winning (U=9143.00/3302.00/15682.00; p=0.583/0.591/0.393) or placing (U=9086.50/2957.50/15144.00; p=0.659/0.264/0.226). Horses that required a specialist loader were significantly more likely to win than horses that did not (no SL MRD reduced by 46.99; U=1462.50; p=0.042). GLMs identified that specialist loaders were most frequently used with colts and stallions (F(1,335)=5.43; p=0.020). The number of handlers needed to load horses had no significant correlation with finishing position (r=-0.042; p=0.392).

3.3.3 Behaviour inside stalls

A significant difference in behaviour inside stalls was found between horses that placed in the top three and those that did not (H(2)=6.15; p=0.046) when tested with a KW test. MW post-hoc analysis identified that horses exhibiting no adverse behaviour inside stalls were significantly more likely to place than those showing excessive adverse behaviour (EA MRD reduced by 47.81; U=3912.50; p=0.037). More adverse behaviour inside stalls was associated with shorter race distances (F(1,511)=5.36; p=0.0006) and no adverse behaviour before loading (F(1,404)=3.35; p=0.036) when tested with GLMs.

3.4 Effect of sweating on performance

A significant difference was found between horses that won or did not and the amount of sweating at the start (H(2)=7.45; p=0.024) when tested with a KW test. MW post-hoc analysis identified that horses foaming were significantly more likely to win than horses only sweating (sweating MRD reduced by 8.37; U=616.00; p=0.004).

3.5 Jockey influence on racehorse performance

Removing feet from stirrups, standing in stirrups and dismounting before loading did not significantly influence whether a horse won (U=5040.00/7530.00/4452.00; p=0.215/0.136/0.897) or was placed (U=5155.50/8005.00/4109.50; p=0.533/0.754/0.454). Kicking, whip use and dismounting whilst loading also had no impact on winning (U=2911.00/2274.00/2647.00; p=0.744/ 0.205/0.931) or placing (U=2457.00/2339.00/2072.00; p=0.158/0.496/0.133). However, horses whose jockeys pushed their bodyweight forward in the saddle whilst loading were more likely to place first to fourth than horses whose jockeys did not (MRD reduced by 55.44; U=3428.50; p=0.020).

3.6 Logistic regression to identify variables associated with racehorse performance

3.6.1 Model A: ‘win’ or ‘no win’

Six variables were significantly associated with winning at a univariate level and were entered into the multivariate model. The Hosmer Lemeshow statistic to test goodness of fit showed a moderate fit (X^2=11.31; p=0.185), and Omnibus tests of model coefficients showed a significance level of p<0.05 after removal of each variable. Analysis of the ROC curve determined that the model had good predictability (ROC=71%).

Two variables were significantly associated with a horses’ chance of winning: drawn order and time spent inside stalls (Table 4). Chance of winning was found to be reduced by 15% for every increase in drawn order (p=0.006) and horses inside stalls for longer than 50s were 59% less likely to win than those in stalls for 49s or less (p=0.030). Although insignificant alone, the amount horses sweat improved model fit (p=0.066).

Table 4: Final Multivariate Model A (chance of winning). [1]P-value = probability; [2]B-value = estimated parameter to represent change of 1n of odds regarding the dependent variable; [3]Ref = reference category.

Backwards stepwise (LR)	**Total (n=423) n per category**	**P-value[1]**	**Odds ratio**	**95% confidence interval**	**B-value[2]**
Drawn order	423	0.006	0.857	0.767; 0.956	-0.155
Over/under 50s	423	0.030	0.414	0.187; 0.919	-0.882
Sweating		0.066			
Not sweating	354	Ref[3]			
Sweating	49	0.122	0.316	0.073; 1.360	-1.153
Foaming	20	0.102	2.515	0.833; 7.596	0.922

3.6.2 Model B: ‘place’ or ‘no place’

Eight variables were significantly associated with horses placing in races at a univariate level and were taken into the multivariate model. The Hosmer Lemeshow statistic to test goodness of fit showed a good fit (X^2=9.25; p=0.321), and Omnibus tests of model coefficients showed a significance level of p<0.05 after removal of each variable. Analysis of the ROC curve determined that the model had moderate predictability (ROC=68%).

Three variables were significantly associated with a horses’ chance of placing in races: horse age, behaviour inside stalls (recoded as a binary variable) and field size (Table 5). A horse’s chance of placing first to third was found to be reduced by 13% for every additional year of age in races open to multiple age groups (p=0.014). Moderate or excessive adverse behaviour inside stalls reduced the chance of placing by 52% compared to horses showing no adverse behaviour (p=0.011). For every additional horse in the field, the chance of placing was reduced by 17% (p=0.0001). Time spent inside stalls improved model fit, but was not significant alone (p=0.104).

Table 5: Final multivariate Model B (chance of placing). [1]P-value = probability; [2]B-value = estimated parameter to represent change of 1n of odds regarding the dependent variable.

Backwards stepwise (LR)	**Total (n=411) n per category**	**P-value[1]**	**Odds ratio**	**95% confidence interval**	**B-value[2]**
Age of horse	411	0.014	0.868	0.776; 0.972	-0.141
Time in stall	411	0.104	0.994	0.988; 1.001	-0.006
Behaviour in stall	411	0.011	0.482	0.275; 0.844	-0.730
Field size	411	0.0001	0.834	0.759; 0.916	-0.182

4.0 DISCUSSION

Time horses spent inside stalls, behaviour before loading, behaviour inside stalls and the extent to which horses sweat before racing were all linked to racehorse performance. Behaviour during loading, the use of loading aids (excluding specialist loaders) and jockey behaviours (excluding pushing forwards during loading) had no significant impact on performance. Different factors impacted whether horses won (drawn order and time in stalls) or placed (age, behaviour in stalls and field size). Performance in sport, including horse racing is multifaceted; marginal gains theory proposes that focusing on small improvements in specific aspects of performance can enhance overall success through the aggregation of improvements within these smaller marginal gains (Williams, 2013). The variables associated with the start of the race identified here to affect racehorse performance could provide an insight to racehorse trainers for how to incur a performance advantage by addressing these marginal gains. For example, loading behaviour and habituating horses to stand quietly within starting stalls could be addressed in training to reduce the negative impact of moderate or adverse behaviour once loaded, and the subsequent negative impact on race success.

4.1 *Time spent in stalls*

Horses that spent over 50s inside starting stalls were 59% less likely to win ($p<0.05$). This supports the notion that a longer interval between warm-up and exercise negates the positive physiological effects of warming up, including increased HR and accelerated VO_2 kinetics (Jansson *et al*., 2005; Silva *et al*., 2018; Chatel *et al*., 2020). Galazoulas *et al*. (2012) suggested that avoiding rest post-warm-up increases performance of ‘explosive’ tasks in humans. The current results suggest this could be applied to horseracing – an ‘explosive’ and high-velocity sport – disadvantaging horses spending longer than 50s stationary inside stalls. To reduce this disadvantage, modifications to the rules of racing could introduce a maximum number of loading attempts before unwilling horses are withdrawn to reduce time other horses are inside stalls, instead of delaying the start of the race.

The lack of a meaningful relationship between time spent in starting stalls and finishing position could suggest that time in stalls is less influential for losing horses. Performance is multifactorial (Marlin and Williams, 2020) with a myriad of factors determining finishing position. In losing horses, lack of individual ability or fitness and fatigue likely play a bigger role in failure to perform, especially in juvenile races (31% of races included in this cohort). Many racehorses are retired in their first or second season due to lack of ability (More, 1999; Thiruvenkaden *et al*., 2009). Lack of ability may also explain why the number of handlers a horse required and drawn order, which previous literature suggests affects performance (Mota *et al*., 2005; Pudaruth *et al*., 2013), were not correlated with finishing position. Whilst the average OR for rated horses (85.5% of runners) studied in this research was 64.3, 79 horses did not have a rating, meaning they had not won a race or placed in the top six in three races. Only five horses studied were rated over 100. Further research utilising a more experienced cohort in listed and group races may reduce the confounding impact of individual ability on findings.

Loading earlier and a larger field size have been linked to poor performance in previous literature (Hitchens *et al*., 2010; Williams *et al*., 2013a) and were associated with horses spending longer inside stalls here. For every increase in field size, horses were 17% less likely to place ($p<0.001$), which is likely due to additional competition but could also be linked to increased loading time meaning some horses are required to wait inside stalls for longer. In races with under nine horses, average time between the first and last horse loading was 46s, compared to 83s for races with nine or more horses. The average time horses spent inside stalls in fields of less than nine horses was 27.17±23.58s compared to 44.54±37.47s for fields of nine horses or more. Although field size was not significantly linked to racehorse behaviour at the start, when loading or inside stalls, the increased waiting time in horses loading earlier in larger fields may be detrimental to performance due to an increased interval between warm-up and performance.

4.2 Racehorse behaviour at the start

4.2.1 Racehorse behaviour before loading

Horses showing moderate adverse behaviour were more likely to win than those showing no adverse behaviour before loading ($p<0.01$). This is concurrent with the findings of McBride and Mills (2012) who suggested pre-race psychological stress and anticipation in Thoroughbreds enhances performance but that overly-aroused horses are more difficult to handle, waste energy before racing and can get distracted enough to detract from performance as their individual zones of optimal functioning (Hanin, 2000) are exceeded. Having greater arousal responses and therefore being more reactive to stimuli such as stalls opening allows racehorses to start faster (McGreevy and Thomson, 2006; Cully *et al*., 2018), which is considered anecdotally to enhance race performance, especially in shorter races. Jockeys interviewed by Jackman *et al*. (2015) expressed that a good start was vital for establishing a flow during the race, with horses missing the break, acquiring poor racing positions and forcing jockeys to significantly alter their race plans being detrimental to race flow and subsequent performance. Both the findings of this research and McBride and Mills (2012) refute Hutson and Haskell's (1997) suggestion that horses most relaxed at the start were likeliest to win. Some horses classed as exhibiting no adverse behaviour in the present study stood stationary by the starting gate before racing for extended periods; although these horses were not over-expending energy, they were not staying warmed up compared to those exhibiting moderate or excessive adverse behaviours. Highlighting the importance of keeping horses warmed up at the start may be beneficial to trainers and jockeys in implementing pre-race strategies in future.

While this research utilised video recordings unlike Hutson and Haskell (1997) so footage could be reviewed more than once, the accuracy of the scoring method used should be considered. More footage of race ‘favourites’ (likely to be more talented) was available so there were more opportunities to visualise adverse behaviours in these horses, which may be a factor in horses showing moderate adverse behaviour winning more frequently. Excluding horses not visible for a sufficient time and scoring behaviour by the number of different behaviours visualised as opposed to individual markers intended to reduce this bias, however, some horses classed as exhibiting ‘no adverse behaviour’ may have been exhibiting adverse behaviours out of shot. Utilising a combination of on-site data collection and video footage in future is advisable to ensure all horses are assessed equally.

4.2.2 Racehorse willingness to load and loading aids

Willingness to load did not affect performance ($p>0.05$), which may be ascribable to the experience of horses sampled or the sensitivity of the approach used to measure behaviours. Using a trinary variable may have been useful to differentiate between levels of unwillingness. Horses were required to hesitate for a minimum of three seconds when loading into stalls to be classed as unwilling, which is unlikely to affect horses as physiologically as rearing or forceful evasion. Such behaviours could be indicative of increased stress, so these horses may be more at risk of exceeding their individual zones of optimal functioning and consequently starting slowly or overrunning during the race (Mukai *et al*., 2007). However, whether this over-arousal is permanent or transient should be considered. Just seven horses showing unwilling behaviour during loading showed adverse behaviour both before and after loading too, with 56.31% of horses who were unwilling to load showing no adverse behaviour before or after the loading process. This implies that the long-term effect of over-arousal during the loading process is minimal, which may explain the lack of a significant effect of loading behaviour on performance. Increasing specificity to differentiate between reluctant and performance-compromising behaviour in future might provide a more comprehensive insight into the effects of resisting loading on performance.

Whilst using straps, blindfolds or stall blankets did not affect performance (p>0.05), the presence of specialist loaders increased the chance of horses winning races (p<0.05). It could be presumed that these horses were more talented and worth persevering with despite behavioural challenges. This is supported by the increased average OR of horses that required a specialist loader (with: 61; without: 55).

4.2.3 Racehorse behaviour inside stalls

Horses were more likely to finish in the top three when no adverse behaviour was exhibited inside stalls as opposed to excessive adverse behaviour (p<0.05) and were 52% less likely to place when showing any adverse behaviour inside stalls (p<0.05). Not only were horses showing no adverse behaviour inside stalls less likely to expend their finite anaerobic capacity before racing, but these horses were less likely to get distracted enough to miss the start, which is deleterious for tactical race positioning (McBride and Mills, 2012; Pudaruth *et al*., 2013). This highlights the importance of desensitising and training horses to stand inside stalls for a prolonged period. This could be achieved by utilising learning theory to initiate changes in behaviour with mental and physical practice (Bolwell *et al*., 2012; Hori *et al*., 2016; McLean and Christensen, 2017).

More adverse behaviour inside stalls was associated with shorter races (p<0.001). Races over shorter distances were more likely to be those for juveniles, who have less experience and consequently exhibit additional stress responses. Increased adverse behaviour over shorter distances could also be due to differences in bloodlines, which influence behaviour, between ‘sprinters’ and ‘stayers’ (Binns *et al*., 2010). Although fewer adverse behaviours before loading were linked to more adverse behaviours inside stalls ($p<0.05$), the cause of this association is difficult to predict in the absence of a cross-over design.

4.3 Sweating

Contrary to anecdotal opinion and previous research (Jackman *et al*., 2015; Ahern, 2020), horses classed as foaming were more likely to win than horses sweating less in this project ($p<0.05$). Sweating was utilised in the present study as a visible marker of a) temperature stress, b) anxiety, distress, excitement, or anticipation or c) pain or anticipation of pain. The latherin component of sweat that causes it to appear 'foamy' is an adaptation to increase surface area and enhance cooling (McDonald *et al*., 2009). More adverse behaviour before loading was associated with sweating ($p<0.05$), which supports the concept that horses sweat more when stressed, however, this was not replicated for horses foaming despite the theory that excessive electrolyte losses from sweating profusely damage performance (Mitchell, 2018). In future, expanding the sweating variable used may differentiate between horses foaming slightly and those coated in foam (Wagner, 2010), as some horses classed as foaming here presented with foam between their hindlegs but appeared otherwise dry. It may also be valuable to begin observations earlier in the pre-parade or parade ring to account for events triggering excessive stress and sweating before horses arrive at the start. As horses sweating to the point of foaming would likely have been sweating for a longer period, beginning observations earlier to account for the sweat-eliciting event may be central to establishing why these horses appear to be at a performance advantage.

As bloodlines influence equine behaviour, anecdotally they are also considered to influence how much racehorses sweat within the racing fraternity. One common sire and three common dam-sires were located in the 26 horses classed as foaming, which could suggest that these horses were predisposed to sweat to a greater extent. Research investigating heritability of performance itself is mixed (Mota *et al*., 2005; Thiruvenkaden *et al*., 2009;

McBride and Mills, 2012), but research looking specifically at bloodlines concerning pre-race behaviour and sweating may be warranted. Of the repeated horses included in this study, two foamed up at the start on one occasion and not the other. One horse performed better when not sweating (not sweating: 2nd; foaming: 7th) and the other finished 8th on both occasions. This is contrary to the cohort results, highlighting the need for further longitudinal research in this area. As the average OR was higher (61) for horses foaming than those sweating (58) or not sweating (54), longitudinal research would also exclude the extraneous variable of ability, which is likely to be partially responsible for the result of the present study.

4.4 Jockey influence

Previous research has highlighted the impact of the jockey on performance (Williams, 2013; Williams and Tabor, 2017), however only pushing bodyweight forwards in the saddle during loading influenced whether horses placed first to fourth ($p<0.05$). The contribution of the jockey is critical during the race for implementation of racing tactics (Evans and McGreevy, 2011; Williams *et al*., 2013b), whereas psychological dynamics between horses and jockeys that may be more influential before racing are less established in literature (von Lewinski *et al*., 2013). The lack of jockey influence demonstrated here could be due to study design, as jockey behaviours were likely to be missed when horses were out of shot. As with equine behaviour variables, on-site data collection would be beneficial to ensure all horse and jockey dyads are always visible. Further research should also consider the influence of stalls handlers on how horses behave and how easily they load into stalls, as well as the interactive effect of stalls handlers and jockeys.

4.5 Limitations and future research

A recurrent limitation in the present study was the use of footage to collect data. On-site data collection would be a better approach in future, although this was impossible for the current study due to restrictions as a result of the Covid-19 pandemic. Additionally, collecting data on-site arguably would increase accuracy when measuring sweating, which was occasionally difficult to determine using televised footage. Using HR and HR variability (Krzywanek *et al*., 1970; Mukai *et al*., 2007; Hall *et al*., 2018) concurrently with behavioural observations in future would be invaluable to better ascertain stress levels in horses.

Individual ability is the largest extraneous variable in this project. Although OR was included in analysis, longitudinal research of the same horses (More, 1999) would be optimal in future. It would be interesting to measure if the effect of the variables assessed here change in Class one pattern (graded) and listed races (highest level of flat racing performance in the UK). There is variety in talent in all races, but none more so than juvenile races where ability may be more influential in racehorse finishing position, as horses that will be retired following their first season are still racing (Thiruvenkaden *et al*., 2009).

5.0 CONCLUSION

This study aimed to assess how the start of flat races affected racehorse performance. Showing moderate adverse behaviour before loading, loading with a specialist loader and foaming at the start increased a horse’s chance of winning, whereas showing no adverse behaviour inside stalls increased the chance of placing. Spending longer than 50s inside starting stalls decreased the chance of winning and placing. Willingness to load, other loading aids and most jockey actions did not affect performance.

Although more research is warranted by the results of this study, findings may be beneficial to racehorse trainers by highlighting the benefits of appropriate gate training in young horses to reduce occurrence of adverse behaviours inside stalls. Additionally, stressing the importance of the warm-up period pre-race could allow trainers and jockeys to develop tactics for race preliminaries in addition to the race itself. Findings may also be used to justify alterations to the current rules of British racing regarding race preliminaries and the loading process to improve and maintain the integrity of the sport.

ACKNOWLEDGEMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors would like to thank Chelmsford City Racecourse, specifically Fraser Garrity and Neil Graham, for their advice and enthusiasm regarding this study despite Covid restrictions preventing on-site collection of data.

REFERENCES

Ahern, T. (2020) 'Medical Conditions that could Contribute to the Incidence of Transport-Related Problem Behaviours in Equids.', *World*, 8, pp.4-8. doi: 10.12970/2310-0796.2020.08.02

Bakovic, D., Pivac, N., Zubin Maslov, P., Breskovic, T., Damonja, G. and Dujic, Z. (2013) 'Spleen volume changes during adrenergic stimulation with low doses of epinephrine.', *J Physiol Pharmacol*, 64(5), pp.649-655. Available at: http://www.jpp.krakow.pl/journal/archive/10_13/pdf/649_10_13_article.pdf (Accessed: 28 January 2021)

BHA (2021a) *The Rules of Racing: Part 3 - The Start*. Available at: http://oldrules.britishhorseracing.com/Orders-and-rules&staticID=126334&depth=3 (Accessed: 7 January 2021).

BHA (2021b) *The Rules of Racing: Starting Procedures*. Available at: http://oldrules.britishhorseracing.com/Orders-and-rules&staticID=126402&depth=3 (Accessed: 3 January 2021).

BHA (2021c) *The Rules of Racing: Stalls Tests*. Available at: http://oldrules.britishhorseracing.com/Orders-and-rules&staticID=126789&depth=3 (Accessed: 8 January 2021).

Binns, M.M., Boehler, D.A. and Lambert, D.H. (2010) 'Identification of the myostatin locus (MSTN) as having a major effect on optimum racing distance in the Thoroughbred horse in the USA.', *Animal genetics*, 41, pp.154-158. doi: 10.1111/j.1365-2052.2010.02126.x

Bolwell, C.F., Rogers, C.W., French, N.P. and Firth, E.C. (2012) 'Associations between yearling exercise and interruptions during race training in Thoroughbred racehorses.', *American journal of veterinary research*, 73(10), pp.1610-1616 doi: 10.2460/ajvr.73.10.1610

Bosholn, M. and Anciaes, M. (2018) 'Focal animal sampling', *Encyclopedia of Animal Cognition and Behavior*, pp.1-3. doi: 10.1007/978-3-319-47829-6_262-1

Brown, C.D. and Davis, H.T. (2006) 'Receiver operating characteristics curves and related decision measures: A tutorial.', *Chemometrics and intelligent laboratory systems*, 80(1), pp.24-38. doi: 10.1016/j.chemolab.2005.05.004

Burnley, M. and Jones, A.M. (2007) 'Oxygen uptake kinetics as a determinant of sports performance.', *European Journal of Sport Science*, 7(2), pp.63-79. doi: 10.1080/17461390701456148

Chatel, M.M., Tabor, G., Williams, J.R. and Williams, J.M. (2020) 'An evaluation of factors affecting show jumping warm-up on subsequent show jumping performance in 1.30 m class.', *Comparative Exercise Physiology*, pp.1-14. doi: 10.3920/CEP200026

Cheetham, J., Riordan, A.S., Mohammed, H.O., McIlwraith, C.W. and Fortier, L.A. (2010) 'Relationships between race earnings and horse age, sex, gait, track surface and number of race starts for Thoroughbred and Standardbred racehorses in North America.', *Equine Veterinary Journal*, 42(4), pp.346-350. doi: 10.1111/j.2042-3306.2010.00032.x

Cully, P., Nielsen, B., Lancaster, B., Martin, J. and McGreevy, P. (2018) 'The laterality of the gallop gait in Thoroughbred racehorses', *Plos one*, 13(6), pp.e0198545. doi: 10.1371/journal.pone.0198545

Dyson, S. (2018) 'Development of an ethogram for a pain scoring system in ridden horses and its application to determine the presence of musculoskeletal pain.', *Journal of veterinary behavior*, 23, pp.47-57. doi: 10.1016/j.jveb.2017.10.008

Evans, D. and McGreevy, P. (2011) ' An investigation of racing performance and whip use by jockeys in Thoroughbred races.', *PLoS One*, 6(1), pp.e15622. doi: 10.1371/journal.pone.0015622

Galazoulas, C., Tzimou, A., Karamousalidis, G. and Mougios, V. (2012) 'Gradual decline in performance and changes in biochemical parameters of basketball players while resting after warm-up.', *European journal of applied physiology*, 112(9), pp.3327-3334. doi: 10.1007/s00421-012-2320-1

Gould, D. and Udry, E. (1994) 'Psychological skills for enhancing performance: Arousal regulation strategies.', *Medicine & Science in Sports & Exercise*, 26(4), 478–485. doi: 10.1249/00005768-199404000-00013

Great British Racing (2022) *'The History of Great British Racing*'. Available at: https://www.greatbritishracing.com/about/history/ (Accessed: 31 January 2022)

Hall, C., Randle, H., Pearson, G., Preshaw, L. and Waran, N. (2018) 'Assessing equine emotional state', *Applied Animal Behaviour Science*, 205, pp.183-193. doi: 10.1016/j.applanim.2018.03.006

Hanin, Y. (2000) 'Individual zones of optimal functioning (IZOF) model.' In *Emotions in Sport*, Human Kinetics, Vancouver, pp. 65-89

Hayes, A.F., Glynn, C.J. and Huge, M.E. (2012) 'Cautions regarding the interpretation of regression coefficients and hypothesis tests in linear models with interactions.', *Communication Methods and Measures*, 6(1), pp.1-11. doi: 10.1080/19312458.2012.651415

Hitchens, P.L., Blizzard, C.L., Jones, G., Day, L. and Fell, J. (2010) 'Predictors of race-day jockey falls in flat racing in Australia.', *Occupational and Environmental Medicine*, 67(10), pp.693-698. doi: 10.1136/oem.2009.050567

Hori, Y., Tozaki, T., Nambo, Y., Sato, F., Ishimaru, M., Inoue-Murayama, M. and Fujita, K. (2016) 'Evidence for the effect of serotonin receptor 1A gene (HTR 1A) polymorphism on tractability in Thoroughbred horses.', *Animal genetics*, 47(1), pp.62-67. doi: 10.1111/age.12384

Hughes, M. (2004) 'Notational analysis - a mathematical perspective', *International Journal of Performance Analysis*, 4(2), pp.97-139. doi: 10.1080/24748668.2004.11868308

Hughes, M. and Franks, I.M. eds. (2004) *Notational analysis of sport: Systems for better coaching and performance in sport*. Psychology Press.

Hutson, G.D. and Haskell, M.J. (1997) 'Pre-race behaviour of horses as a predictor of race finishing order', *Applied Animal Behaviour Science*, 53(4), pp.231-248. doi: 10.1016/S0168-1591(96)01162-8

Jackman, P., Van Hout, M.C., Lane, A. and Fitzpatrick, G. (2015) 'Experiences of flow in jockeys during flat-race conditions., *International journal of sport and exercise psychology*, 13(3), pp.205-223. doi: 10.1080/1612197X.2014.956327

Jansson, A. (2005) 'A field study on warm-up regimes for Thoroughbred and Standardbred racehorses.', *Equine and Comparative Exercise Physiology*, 2(4), pp.219-224. doi: 10.1079/ECP200572

Kaiser, L., Heleski, C.R., Siegford, J. and Smith, K.A. (2006) 'Stress-related behaviors among horses used in a therapeutic riding program.', *Journal of the American veterinary medical association*, 228(1), pp.39-45. doi: 10.2460/javma.228.1.39

Krzywanek, H., Wittke, G., Bayer, A. and Borman, P. (1970) The heart rates of Thoroughbred horses during a race, *Equine Veterinary Journal*, 2(3), pp.115-117. Doi: 10.1111/j.2042-3306.1970.tb04170.x

Legg, K., Cochrane, D., Gee, E. and Rogers, C. (2020) 'The External Workload of Thoroughbred Horse Racing Jockeys.', *Sustainability*, 12(18), pp.7572.
doi: 10.3390/su12187572

Lindinger, M.I. (2008) 'Sweating, dehydration and electrolyte supplementation: Challenges for the performance horse.', In *Proceeding of the 4th European Eq. Nutrition & Health Congress. Netherlands* (pp. 18-19). Available at: https://www.equine-congress.com/uploads/files/file/54/sweating-dehydration-and-electrolyte-supplementation-challenges-for-the-performance-horse.pdf (Accessed on: 29 February 2021)

Manikandan, S. (2011) 'Measures of central tendency: median and mode', *Journal of pharmacology and pharmacotherapeutics*, 2(3), pp.214-215. doi: 10.4103/0976-500X.83300

Marlin, D. and Williams, J. (2020) 'Faults in international showjumping are not random', *Comparative exercise physiology*, 16(3), pp.235-241. doi: 10.3920/CEP190069.

McBride, S.D. and Mills, D.S. (2012) 'Psychological factors affecting equine performance', *BMC veterinary research*, 8(1), pp.1-11. doi: 10.1186/1746-6148-8-180

McConaghy, F.F., Hodgson, D.R., Evans, D.L. and Rose, R.J. (1995) 'Equine sweat composition: effects of adrenaline infusion, exercise and training.', *Equine Veterinary Journal*, 27(S20), pp.158-164. doi: 10.1111/j.2042-3306.1995.tb05023.x

McDonald, R.E., Fleming, R.I., Beeley, J.G., Bovell, D.L., Lu, J.R., Zhao, X., Cooper, A. and Kennedy, M.W. (2009) 'Latherin: a surfactant protein of horse sweat and saliva.', *PloS one*, 4(5), pp.e5726. doi: 10.1371/journal.pone.0005726

McGowan, C. (2008) 'Clinical pathology in the racing horse: the role of clinical pathology in assessing fitness and performance in the racehorse.', *Veterinary Clinics of North America: Equine Practice*, 24(2), pp.405-421. doi: 10.1016/j.cveq.2008.03.001

McGreevy, P.D., McLean, A.N., Warren-Smith, A.K., Waran, N. and Goodwin, D. (2005) ‘Defining the terms and processes associated with association’, *Proceedings of the 1st International Equitation Science Symposium 2005*, Melbourne, Australia, 26-27 February. Available at: https://www.researchgate.net/publication/289530030_Defining_the_terms_and_processes_associated_with_equitation (Accessed: 19 November 2020)

McGreevy, P.D. and Thomson, P.C. (2006) 'Differences in motor laterality between breeds of performance horse.', *Applied Animal Behaviour Science*, 99(1-2), pp.183-190. doi: 10.1016/j.applanim.2005.09.010

McLean, A.N. and Christensen, J.W. (2017) 'The application of learning theory in horse training.', *Applied Animal Behaviour Science*, 190, pp.18-27. doi: 10.1016/j.applanim.2017.02.020

Mitchell, B. (2018) 'The importance of hydration in horses', *Equine health*, 2018(42), pp.14-18. doi: 10.12968/eqhe.2018.42.14

More, S.J. (1999) A longitudinal study of racing Thoroughbreds: performance during the first years of racing, *Australian veterinary journal*, 77(2), pp.105-112. doi: 10.1111/j.1751-0813.1999.tb11678.x

Mota, M.D.S., Abrahão, A.R. and Oliveira, H.N. (2005) 'Genetic and environmental parameters for racing time at different distances in Brazilian Thoroughbreds.', *Journal of animal breeding and genetics*, 122(6), pp.393-399. doi: 10.1111/j.1439-0388.2005.00551.x

Mukai, K., Takahashi, T., Eto, D., Ohmura, H., Tsubone, H. and Hiraga, A. (2007) Heart rates and blood lactate response in Thoroughbred horses during a race, *Journal of Equine Science*, 18(4), pp.153-160. doi: 10.1294/jes.18.153

Mukaka, M.M. (2012) 'A guide to appropriate use of correlation in medical research.', *Malawi Medical Journal*, 24(3), pp.69-71. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3576830/ (Accessed: 13 January 2021)

Munsters, C., van den Broek, J., van Weeren, R. and van Oldruitenborgh-Oosterbaan, M.M.S. (2013) ‘The effects of transport, riot control training and night patrols on the workload and stress of mounted police horses’, *Applied Animal Behaviour Science*, 143(1), pp.52-60. doi: 10.1016/j.applanim.2012.10.019

Nachar, N. (2008) 'The Mann-Whitney U: A test for assessing whether two independent samples come from the same distribution.', *Tutorials in quantitative methods for psychology*, 4(1), pp.13-20. doi: 10.20982/TQMP.04.1.P013

Pierard, M., McGreevy, P. and Geers, R. (2019) 'Reliability of a descriptive reference ethogram for equitation science.', *Journal of Veterinary Behavior*, 29, pp.118-127. doi: 10.1016/j.jveb.2018.10.001

Pudaruth, S., Medard, N. and Dookhun, Z.B. (2013) 'Horse Racing Prediction at the Champ De Mars using a Weighted Probabilistic Approach.', *International Journal of Computer Applications*, 72(5), pp.39-42. doi: 10.5120/12493-9048

Ryan, K., Garruppo, G., Alexander, K., Hluchan, C.M. and Lincoln, A.E. (2020) 'Injuries among Maryland jockeys during thoroughbred racing: 2015–2019.', *BMJ Open sport and exercise medicine*, 6(1), pp.e000926. doi: 10.1136/bmjsem-2020-000926

Schober, P., Bossers, S.M. and Schwarte, L.A. (2018a) 'Statistical significance versus clinical importance of observed effect sizes: what do P values and confidence intervals really represent?', *Anaesthesia and analgesia*, 126(3), pp.1068.
doi: 10.1213/ANE.0000000000002798

Schober, P., Boer, C. and Schwarte, L.A. (2018b) 'Correlation coefficients: appropriate use and interpretation.', *Anaesthesia and Analgesia*, 126(5), pp.1763-1768.
doi: 10.1213/ANE.0000000000002864

Silva, L.M., Neiva, H.P., Marques, M.C., Izquierdo, M. and Marinho, D.A. (2018) 'Effects of warm-up, post-warm-up, and re-warm-up strategies on explosive efforts in team sports: A systematic review.', *Sports medicine*, 48(10), pp.2285-2299. doi: 10.1007/s40279-018-0958-5

Smith, L.J., Tabor, G. and Williams, J. (2020) 'A retrospective case-control study to investigate horse and jockey level risk factors associated with horse falls in Irish Point-to-Point races.', *Comparative exercise physiology*, 16(3), pp.225-234. doi: 10.3920/CEP190054

Sperandei, S. (2014) 'Understanding logistic regression analysis', *Biochemia medica*, 24(1), pp.12-18. doi: 10.11613/BM.2014.003

Tamura, N., Kodaira, K., Yoshihara, E., Mae, N., Yamazaki, Y., Mita, H., Kuroda, T., Fukuda, K., Tomita, A. and Kasashima, Y. (2018) 'A retrospective cohort study investigating risk factors for the failure of Thoroughbred racehorses to return to racing after superficial digital flexor tendon injury.', *The Veterinary Journal*, 235, pp.42-46. doi: 10.1016/j.tvjl.2018.03.003

Tanner, J.C., Rogers, C.W. and Firth, E.C. (2013) 'The association of 2-year-old training milestones with career length and racing success in a sample of Thoroughbred horses in New Zealand.', *Equine Veterinary Journal*, 45(1), pp.20-24. doi: 10.1111/j.2042-3306.2011.00534.x

Thiruvenkaden, A.K., Kandasamy, N. and Panneerselvam, S. (2009) 'Inheritance of racing performance of Thoroughbred horses.', *Livestock science*, 121(2-3), pp.308-326. doi: 10.1016/j.livsci.2008.07.009

Thompson, C. (2009) 'Descriptive data analysis', *Air medical journal*, 28(2), pp.56-59. doi: 10.1016/j.amj.2008.12.001

Vazzana, I., Rizzo, M., Dara, S., Niutta, P.P., Giudice, E. and Piccione, G. (2014) 'Haematological changes following reining trials in quarter horses.', *Acta Scientiae Veterinariae*, 42(1), pp.1-5. doi:doi number. Available at: https://www.redalyc.org/pdf/2890/289029240003.pdf (Accessed on: 19 January 2021)

Visser, E.K., VanDierendonck, M., Ellis, A.D., Rijksen, C. and Van Reenen, C.G. (2009) 'A comparison of sympathetic and conventional training methods on responses to initial horse training.', *The Veterinary Journal*, 181(1), pp.48-52. doi: 10.1016/j.tvjl.2009.03.009

von Borstel, U.U. and Keil, J. (2012) 'Horses' behavior and heart rate in a preference test for shorter and longer riding bouts.', *Journal of veterinary behaviour*, 7(6), pp.362-374. doi: 10.1016/j.jveb.2012.02.006

von Borstel, U.U., Duncan, I.J.H., Shoveller, A.K., Merkies, K., Keeling, L.J. and Millman, S.T. (2009) 'Impact of riding in a coercively obtained Rollkur posture on welfare and fear of performance horses.', *Applied Animal Behaviour Science*, 116(2-4), pp.228-236. doi: 10.1016/j.applanim.2008.10.001

von Lewinski, M., Biau, S., Erber, R., Ille, N., Aurich, J., Faure, J.M., Möstl, E. and Aurich, C. (2013) 'Cortisol release, heart rate and heart rate variability in the horse and its rider: Different responses to training and performance.', *The Veterinary Journal*, 197(2), pp.229-232. doi: 10.1016/j.tvjl.2012.12.025

Wagner, A.E. (2010) 'Effects of stress on pain in horses and incorporating pain scales for equine practice.', *Veterinary Clinics: Equine Practice*, 26(3), pp.481-492. doi: 10.1016/j.cveq.2010.07.001

Waller, A.E., Daniels, J.L., Weaver, N.L. and Robinson, P. (2000) 'Jockey injuries in the United States', *Jama*, 283(10), pp.1326-1328. doi: 10.1001/jama.283.10.1326

Williams, J.M. (2013) 'Performance analysis in equestrian sport', *Comparative exercise physiology*, 9(2), pp.67-77. doi: 10.3920/CEP13003

Williams, J.M. and Tabor, G. (2017) 'Rider impacts on equitation', *Applied animal behaviour science*, 190, pp.28-42. doi: 10.1016/j.applanim.2017.02.019

Williams, J.M., Marks, F., Mata, F. and Parkin, T. (2013a) 'A case control study to investigate risk factors associated with horse falls in steeplechase races at Cheltenham racetrack.', *Comparative exercise physiology*, 9(1), pp.59-64. doi: 10.3920/CEP13005

Williams, J.M., Heath, Y. and Mata, F. (2013b) 'Beating the odds: using epidemiology to pick the Cheltenham Gold Cup winner.', *The Veterinary Nurse*, 4(1), pp.48-52.
doi: 10.12968/vetn.2013.4.1.48

Yap, B.W. and Sim, C.H. (2011) 'Comparisons of various types of normality tests.', *Journal of statistical computation and simulation*, 81(12), pp.2141-2155.
doi: 10.1080/00949655.2010.520163

Yngvesson, J., de Boussard, E., Larsson, M. and Lundberg, A. (2016) 'Loading horses (Equus caballus) onto trailers—Behaviour of horses and horse owners during loading and habituating.', *Applied animal behaviour science*, 184, pp.59-65.
doi: 10.1016/j.applanim.2016.08.008

TABLES

Table 1: Ancillary methods (loading aids) used to facilitate the successful and safe loading of racehorses into starting stalls (also known as starting gates or barriers) (Ahern, 2020).

Table 2: Ethogram to measure adverse behaviour before loading and when waiting inside stalls (McGreevy *et al.*, 2005; Kaiser *et al*., 2006; Visser *et al*., 2009; von Borstel *et al*., 2009; von Borstel and Keil, 2012; Munsters *et al*., 2013; Peirard *et al*., 2019).

Table 3: Ethogram to measure willingness to go forward (Yngvesson *et al*., 2016; Dyson, 2018)

Table 4: Final Multivariate Model A (chance of winning). [1]P-value = probability; [2]B-value = estimated parameter to represent change of 1n of odds regarding the dependent variable; [3]Ref = reference category.

Table 5: Final multivariate Model B (chance of placing). [1]P-value = probability; [2]B-value = estimated parameter to represent change of 1n of odds regarding the dependent variable.

FIGURES

Figure 1: Starting stalls, also known as starting gates or barriers, are used to release horses simultaneously at the beginning of the race for a fair start. (Photo: Author IW's own)

Figure 2: Horses are loaded into starting stalls prior to racing by a team of qualified handlers. (Photo: Author IW's own)

Figure 3: Chelmsford City Racecourse is a left-handed track with an all-weather polytrack surface, sweeping bends, two two-furlong straights and chutes for seven furlong, one and two mile starts. It is just over a mile in circumference, and is located in Essex in the east of England, UK (51.842°N,0.512°E). It is the newest racecourse in England as of 2022, having opened in 2008. (Photo: At The Races)