EQUINE ENDURANCE RACE PACING STRATEGY DIFFERS BETWEEN FINISHERS & NON-FINISHERS IN 120 km SINGLE-DAY RACES

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Abstract

Race pace strategy has been extensively studied in human sports such as running, cycling and swimming. In contrast, pacing strategy appears to have been virtually ignored in equestrian sport despite the potential for contributing to performance optimisation. The aim of the present study was to analyse data available in the public domain for electronically-timed FEI 120 km (single day) CEI** endurance races that took place in Europe and the Middle East in 2016 and 2017. Competition records for 389 horses in 24 races, each consisting of 4 phases (loops/laps), were evaluated; 56% (n=219) of horses successfully completed the races analysed, with the remaining 44% (n=170) not finishing. The majority of horses that did not finish were withdrawn for gait related reasons (n=125; 74%). Across the duration of the races, horses that successfully finished recorded 7% slower average speeds (P=0.0001) compared to those that did not finish. Loop (lap) speed decreased sequentially throughout races from loop 1> loop 2> loop 3 / final loop for both the horses that completed and those that failed to complete, but the rate of decrease was greater in horses that did not complete.. Horses withdrawn at the first veterinary check for "gait" recorded a 36% faster average speed than those withdrawn at the finish (P=0.0001). Horses withdrawn for "metabolic" reasons at the finish recorded a significant increase in loop speed from loop 3 to the final loop (p=0.02), with their speed increasing by an average of 7% on the final loop. Horses that failed to finish races completed loop 1 at a faster speed than those horses that finished and subsequently had a greater reduction in speed across the remaining loops. In contrast, horses that finished successfully had a slower loop 1 speed and completed subsequent loops at a higher percentage of their loop 1 speed. . Consideration of race pace strategy in equine endurance racing may be a tool to reduce gait and metabolic eliminations and increase the chance of completion.

Word Count: 336

Keywords: competition; equestrian; completion; failure

Introduction

Equine endurance racing has undergone rapid growth in the past 20 years from a minor, predominantly amateur sport to the second largest Federation Equestre Internationale (FEI) discipline after show-jumping since 2007 (having overtaken eventing) with a high level of professional participation (FEI Annual Report, 2015). The sport has seen an increasing level of professional trainers and riders and a dramatic increase in speed at all distances, including the championship distance of 160 km, although there has been an increase in popularity of 120 km, single-day races. Between 1986 and 2002, winning speeds at World Equestrian Games or Endurance World Championships over a one day 160 km distance ranged from 14.8 to 17.8 km/h. However, at the 2004 World Endurance Championships held in Dubai, the average speed of the winning horse was 22.7 km/h and 4 years later on the 12th January 2008 a world record of 24.7 km/h was set; again during a race in the UAE.

In many running or endurance sports such as marathon running, cycling and long distance swimming, the contribution of race strategy or pacing to success has been clearly identified and extensively studied (Abbiss and Laursen, 2008). Pacing strategy describes how an athlete distributes workload throughout an event as opposed to the absolute workload per se. The science of pacing is complex and a variety of different pacing strategies are recognised, including negative (speed increases through event), all-out, positive (speed peaks and then decreases), even, parabolic and variable pacing strategies. The pace a human athlete selects appears to be determined through an extremely complex set of inputs and “a complex algorithm involving peripheral sensory feedback and the anticipated workload remaining” (Abbiss and Laursen, 2008).

In the IAAF World Half-Marathon Championships, Hanley (2015) reported that the best performing male and female athletes maintained their split speeds between 5 km and 15 km, whereas slower athletes had decreased speeds from 5 km onwards. Hanley (2015) also observed that running in packs resulted in smaller decreases in pace compared with athletes who ran alone after 5 km. Santos-Lozano *et al.* (2014) studied a large number of participants in the New York City Marathon (2006-2011) and reported lower variation in speed at 5 km splits in the top runners compared with runners who completed at a slower overall speed. A strong feature of success in human endurance running appears to be low variability in pace (Lambert *et al.* 2004; Ely *et al.* 2008; Haney & Mercer, 2011). Suggested key factors in marathon failure are the selection of unsustainable initial running speeds and the role of psychological factors leading to poor decision making by athletes (Renfree and St Clair Gibson, 2013).

The analysis of race strategy or pacing strategy is particularly well developed and studied in cycling, in both shorter time trials (de Jong *et al.* 2015) and ultracycling events (Heidenfelder et al 2016). One particular advantage of cycling over running is the potential to measure power output in real time in parallel with other variables such as performance and rating of perceived exertion, which may provide further insight into pacing strategy (Konings *et al.* 2017).

The role of pacing strategy in equestrian sport has received little attention. Spence *et al.* (2012) studied race data from 44,803 Thoroughbred racehorses in 3,357 races ranging in length from 1006 to 4225m (50.9-292.9 seconds duration) and observed that better performing horses exhibited race length-dependent pacing strategies which were correlated with the fastest racing times.

It would be anticipated that pacing strategy would have a marked impact on success in equine endurance racing given the length of the races and the potential for different tactics e.g. front-running, use of pacemakers, pack-running, etc. However, to the best of our knowledge there are no peer-reviewed published studies on race pace strategy in equine endurance. The aim of the present study was therefore to conduct a preliminary study using endurance race information available in the public domain to determine if particular strategies were associated with a greater chance of success in 120 km single day races.

Methods & Materials

Competition records for 24, 120 km FEI CEI** level single-day, four phase global endurance races that took place in the 2016 and 2017 seasons were reviewed to compare speed and pacing strategy between horses that finished races and those that were withdrawn for metabolic and gait related reasons. The rules governing these races for 2016 and 2017 are published by the FEI (https://inside.fei.org/sites/default/files/Endurance%20Rules_2017.tracker.pdf). There were no significant differences in the rules related to race structure between 2016 and 2017 races. FEI ** endurance races are defined as races between 120 and 139 km in one day and horses must present for vetting within 20 minutes of arrival at a vet gate and at a pulse of 64bpm or less except at the final vet gate/inspection when the horse must present within 30 minutes. CEI** races must have a minimum of four phases, commonly referred to as "loops". The rules state that no phase may exceed 40 km and should, in principle, be not less than 20 km in length, and cannot be less than 16 km. The last phase/loop is usually the shortest. Thus the structure for races included in this study was: start, phase/loop1, vet gate 1, hold 1, phase/loop2, vet gate 2, phase/loop 3, vet gate 3, phase/loop 4, finish, final veterinary inspection. The races were all ones at which a fully automated electronic timing and results service was provided by Endurance Team Styria (Hahnhofweg 30, 8075 Graz, Austria); an FEI approved timing and results service provider. All races took place in Europe (n=15) or the Middle East (n=9). For each horse that started the race, average speed per loop (lap, km/h) and average speed for the entirety of the race were recorded in the online database. This enabled individual horses' racing strategy to be calculated. The average speed for sequential loops of the course was divided by the speed of each horse during loop 1, and multiplied by 100% to give a percentage marker for each subsequent loop completed relative to loop 1. This strategy marker was used to determine how riders used speed strategically throughout the course of a race.

Data distribution did not meet the requirements for parametric statistical analysis, therefore Mann Whitney U tests were used to establish if there were differences in speed and the strategic approach in the race between horses that completed and those that were withdrawn. A series of Friedman's analyses with *post hoc* Wilcoxon Signed Rank tests was applied to identify any significant differences between loop speeds and average speed, and the strategy deployed within horses that finished and across horses that did not complete. For non-finishers, further analyses evaluated if differences in speed and strategy were related to metabolic or gait related withdrawals, or the stage of the race horses were withdrawn at.

Results

Competition records for 389 horses were evaluated; 56% (n=219) of horses successfully completed the races surveyed, with the remaining 44% (n=170) not finishing. The mean number of starters was 18±13 horses per race; records for horses which were not complete and for horses which were retired by their rider were excluded prior to analysis (n=39). The majority of horses that did not finish, were withdrawn for gait related reasons (n=125; 74%). Gait related withdrawals occurred at a relatively consistent rate at veterinary checks at the conclusion of loops 1 (n=45; 36%), 2 (n=36, 29%) and 3 (n=35, 28%) but were lower at the final veterinary inspection at the finish (n=9; 7%). In contrast, fewer horses were withdrawn for metabolic related reasons (n=46; 26%). The majority of withdrawals occurred at the veterinary inspection for loop 3 of the race (n=32; 70%). No horses were withdrawn on loop 1 for metabolic reasons, with the remaining 30% eliminated from the race after loop 2 (n=7; 15%) or the final veterinary inspection (n=7; 15%).

<u>Race speed</u>

Loop speed decreased sequentially throughout races from loop 1> loop 2> loop 3 for both the horses that completed and those that failed (Figure 1). Interestingly, horses that failed to complete started the race with a faster loop 1 speed but then completed subsequent loops at a slower rate than the horses that finished (Table 1). This relationship was found to be significant, with horses that did not finish completing loop 1 on average 5% faster than horses that did finish (P=0.02). No significant differences in speed were found for loop 2, however horses that finished the race completed loop 3 on average 7% faster than competitors that were eliminated at this stage 3 (P=0.013). Across the whole race, horses that successfully finished recorded 7% slower average speeds (P=0.0001) compared to those that did not finish; although it should be noted that horses which were eliminated will have completed a reduced distanced compared to finishers.

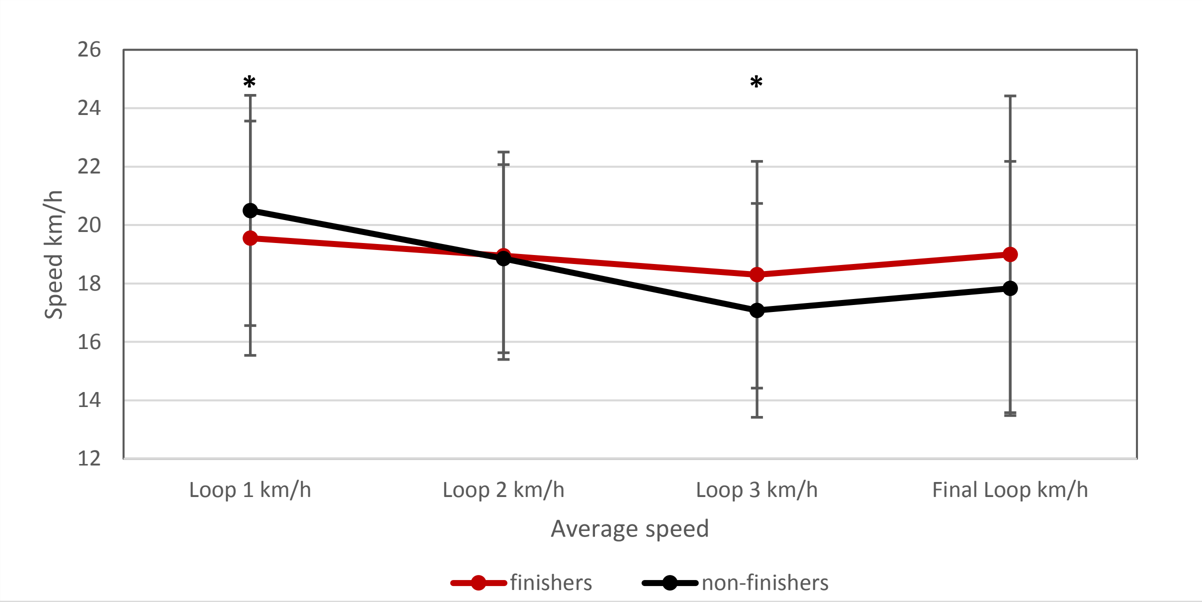

Figure 1: Differences in speed profiles (mean± standard deviation) between endurance horses which successfully completed races (finishers) and horses which were withdrawn (non-finishers); km/h: kilometres per hour; *: significant difference P<0.05.

Table 1: Race speed profiles for horses that did (finishers) and did not complete (non-finishers); km/h: kilometres per hour (mean±SD).

	Loop1 km/h	Loop 2 km/h	Loop 3 km/h	Final Loop km/h	Average whole course km/h
FINISHERS[b]	19.6±4.0	19.0±3.6	18.3±3.9	19.0±5.4	18.8±3.8
NON FINISHERS withdrawn at:					
Vet Gate 1: gait[b]	21.1±4.3				
Vet Gate 2: gait	20.0±4.2	18.4±3.2			19.6±3.7
Vet Gate 3: gait[a]	19.5±3.4	19.4±3.2	18.1±3.9		19.8±3.2
Finish: gait	17.2±3.4	17.0±2.9[a]	15.6±2.8[a]	15.1±2.9	16.2±2.6
Vet Gate 2: metabolic	21.7±3.0	15.9±2.4			
Vet Gate 3: metabolic	21.2±4.1	19.2±3.5	15.9±3.4		
Finish: metabolic[a]	21.9±3.9	20.1±2.1	19.3±2.3[a]	20.6±3.8[a]	20.4±3.0

[a] significant difference in speed within group; [b] significant difference in speed across groups

Non-finishing horses: gait related reasons

No relationship was found between loop 1 speed and which stage of the race horses with gait issues were withdrawn (P>0.05). There were also no differences in speed across races for horses withdrawn due to gait at veterinary gates for loops 1, 2 or 3. However, horses withdrawn for gait at the finish recorded significant variation in loop speeds (P=0.009); *post hoc* analyses revealed an 8% reduction in speed for these from loop 2 to loop 3 (P=0.01). Interestingly, the average speed of horses withdrawn at different points of the race was found to be significantly different from those that finished (P=0.0001). *Post hoc* analyses identified horses withdrawn at the first veterinary check record a 36% faster average speed than those withdrawn at the finish (P=0.0001).

Non-finishing horses: metabolic related reasons

As for gait withdrawals, no relationship was found between loop 1 speed and the stage of the race horses with metabolic issues were withdrawn at (P>0.05). No differences in loop speed were found for horses withdrawn due to metabolic reasons at veterinary gates 1, 2 or 3 (P>0.05). However horses withdrawn for metabolic reasons at the finish recorded significant variation in loop speeds (P=0.03). *Post hoc* analyses identified these differences occurred between loop 3 and final loop (p=0.002) with the average speed of horses withdrawn at the finish increasing by 7% for the final loop, suggesting their subsequent withdrawal could be an indication of the onset of fatigue due to increased competitive effort.

Race pattern

Horses that failed to finish races completed loop 1 at a faster speed than horses that finished (Figure 2). Non-finishers also displayed a reduction in speed across the remaining loops of the race (Table 2). In contrast horses that finished had a slower loop 1 pace but went on to complete subsequent loops at a higher percentage of their loop 1 speed (Table 2). These differences were found to be significant between the groups for loop 2 (P=0.002; 4% increase compared to non-finishers), loop 3 (P=0.0001; 10% increase) and overall race strategy (P=0.0001; 5% increase), with horses that finished on average maintaining a higher percentage of their loop 1 speed throughout the race, suggesting a more successful pacing strategy.

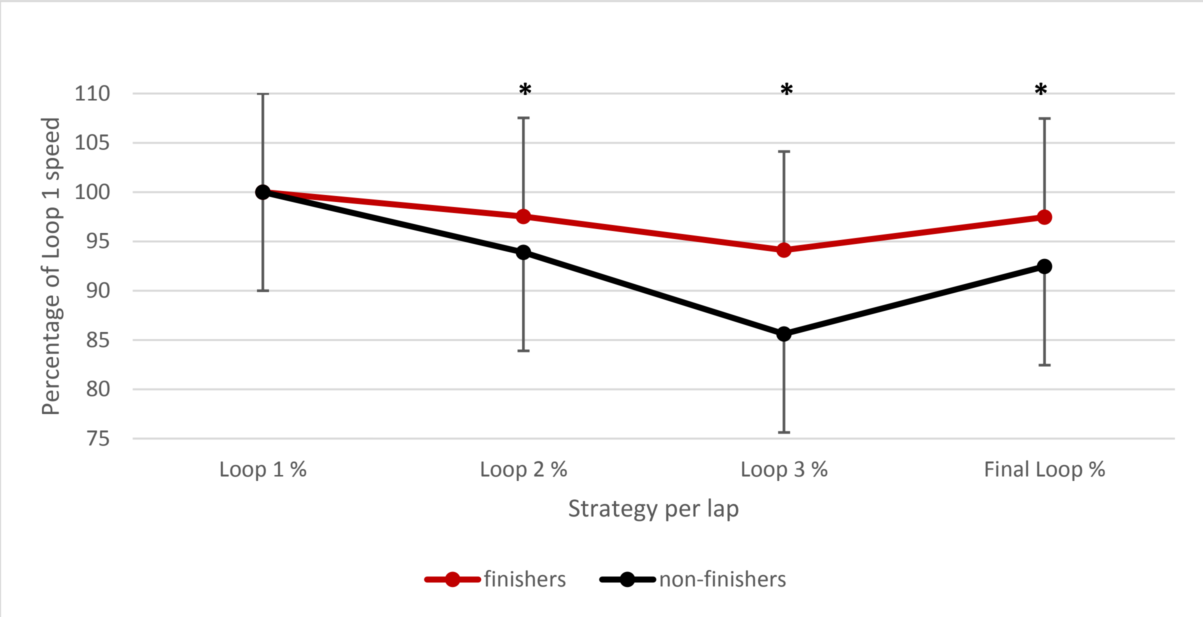

Figure 2: Differences in strategic profiles between endurance horses, which successfully completed races (finishers) and horses, which were withdrawn (non-finishers) expressed as percentage of loop 1 mean speed; *: significant difference P<0.05.

Non-finishing horses: gait related reasons

Significant differences in the strategic approach used by horses withdrawn from the race at the second and third veterinary checks were found. Horses that withdrew at gate 2 recorded a 7% reduction in speed from loop 1 to loop 2 (P=0.02) whilst horses which withdrew at gate 3 recorded a 7% reduction in speed from loop 2 to 3 (P=0.025). It should also be noted that horses which were withdrawn for gait related reasons recorded average faster speeds for loop 1 compared to horses that completed the race.

Non-finishing horses: metabolic related reasons

No specific relationships between the strategic approach used and where horses were withdrawn for metabolic reasons was found (P>0.05). However, the strategic approach adopted on loop 2 appears to be key for horses withdrawn from competition for metabolic reasons (P=0.02). *Post hoc* analyses identified horses withdrawn at the 3rd veterinary check completed loop 2 at a 19% increase of loop 1 speed compared to horses who withdrew at the end of the second loop (P=0.002). Whilst horses withdrawn at the finish completed loop 2 with a 21% increase of loop 1 speed compared to horses who left the race after the second loop (P=0.01). Interestingly, the average loop 1 speed of horses eliminated at the end of the second loop was not significantly higher than horses leaving the race at the third and final veterinary checks (Table 1). This could suggest a lack of fitness may be related to early metabolic withdrawals.

Table 2: Race strategy profiles for horses that completed (finishers) and those that did not complete (non-finishers) expressed as % percentage of loop 1 speed (mean±SD)

	Loop 1 %	Loop 2 %	Loop 3 %	Final Loop %
FINISHERS	100	97.5±7.5	94.1±10.3	97.5±20.2
NON FINISHERS Withdrawn at:				
Vet Gate 1: gait	100			
Vet Gate 2: gait[a1]	100[a1]	93.2±10.6[a1]		
Vet Gate 3: gait[a2]	100[a2]	99.7±7.5[a2]	92.8±12.3	
Finish: gait	100	99.3±7.7	91.7±10.6	89.3±20.0
Vet Gate 2: metabolic[b1, b2]	100	73.5±9.5		
Vet Gate 3: metabolic[b1]	100	91.3±7.0	76.3±13.0	
Finish: metabolic[b2]	100	92.6±8.9	89.1±10.7	94.1±6.1

[a] significant difference in speed within group; [b] significant difference in speed across groups

Discussion

Within endurance races, riders must continuously adapt and maintain the horse's gait and speed to optimise performance (Viry *et al.*, 2015); in effect applying a pacing strategy. The decision riders make on the speed to adopt on each loop of an endurance race would be expected to take into account many factors, including horse fitness, ability, temperament and soundness, course going, terrain and thermal environmental conditions, number of competitors, stage of the race (i.e. loop 1, loop 2, etc) and goal (e.g. completion versus as high a position as possible). In addition, the type of race may influence strategy; for example, over the same course championship races tend to be run at faster speeds than non-championship races (Marlin, unpublished observation).

Our results suggest that pacing strategies used by competitors in FEI CEI** 120 km single day races influence completion rates and therefore competitive success and risk of elimination. The use of inappropriate and highly variable pacing strategies have been associated with poor performance in human endurance running (Ely *et al.* 2008; Haney & Mercer, 2011; Renfree and St Clair Gibson, 2013). Interestingly riders who adopted a more consistent pacing strategy were less likely to be eliminated for metabolic or lameness related problems. In particular, the speed selected to complete loop 1 of races was influential to non-completion. Faster loop 1 speeds was a significant risk factor for subsequent for gait related elimination, therefore riders who selected unsustainable initial speeds on loop 1 were more likely to not complete races. The overall race strategy combined specifically with a consistent loop 2 pace appears key to preventing elimination for metabolic reasons.

Race speed has previously been related to increased levels of horse elimination in endurance races (Fielding *et al.,* 2009; Adamu *et al.,* 2013) leading to suggestions that non-completion could be due to owners and riders selecting inappropriate race strategies to facilitate success (Adamu *et al.,* 2013). In the current study, riders generally adopted a positive pacing strategy from Loop 1 to Loop 3 (loop speed decreasing sequentially) but an increase in speed on the Final loop compared with Loop 3. Whilst combinations that completed races were more consistent in their pacing strategy than eliminated horses, variability in the speeds selected per loop was still observed for finishers (3% reduction from loop 1 to 2; 4% reduction from loop 2 to 3). At elite level, reducing the variability between loops even further, as advocated in human endurance running could produce a marginal gain in performance (Ely *et al.* 2008; Haney & Mercer, 2011) but further studies are needed to determine if this is the case. Opportunities also exist to integrate pacing work into endurance horse training regimens. The use of heart rate monitoring and global positioning systems (GPS) to measure exercise performance, fitness and speed are relatively common within endurance (Bolwell *et al.,* 2015). However, despite this, Bolwell *et al.* (2015) found that only 53% of the riders they surveyed maintained any longitudinal records of their horse’s training activities suggesting further education on monitoring during training to optimise race performance would be beneficial. FEI guidelines also allow riders to use mobile phones or GPS devices to monitor speed within competition (FEI, 2017). Therefore, GPS could be used by riders to accurately identify and monitor speed during races to help them implement consistent pacing strategies potentially improving competition success and optimising equine welfare by increasing completion rates. Further studies evaluating the use of different pacing strategies on endurance horse performance during races and within training are warranted to identify the optimal approach to facilitate completion and protect equine welfare, as well as enhancing competitive success.

Completion rates recorded here are lower than reported by Adamu *et al.*, (2014a; 74%) but similar to Nagy *et al.,* (2014a; 51%). The number of horses eliminated for gait and metabolic related reasons is also higher; the most comprehensive review of endurance racing to date reported 30% lameness related and 9% metabolic related eliminations across 30741 FEI races in 47 countries (Nagy *et al.,* 2014). The differences observed here could be attributed to the specific level of competition analysed combined with the race distance and variation in race terrain and speed (Adamu *et al.,* 2014b; Nagy *et al.,* 2014 a,b). Race location could also have been influential as 50% of races surveyed occurred in Middle East locations, which Nagy *et al.* (2014a, b) reported increased the chance of horses being eliminated due to either metabolic or lameness (gait) reasons.

The increased percentage of eliminations due to lameness found at CEI** level could be associated with the faster pacing strategies used by non-finishers. Endurance horses under certain training and race conditions are exposed to the same high levels of distal limb loading cycles found in thoroughbred racehorses (Bolwell *et al.,* 2015). The magnitude of loading in the distal limb is influenced by the speed of the gait selected as well as ground surface and the accumulative effects of repetitive training and racing. Horses that adopt a racing strategy that includes a fast-paced initial loop will increase the rate of loading cycles, which could aggravate subclinical musculoskeletal issues and may partially explain the high level of gait related eliminations reported across the CEI** races surveyed. Foot pain is consistently reported as a key causal factor in endurance horse lameness (Foss and Wickler, 2004; Mischeff, 2003). Racing at faster speeds over variable terrain causing increased concussion in the feet could also contribute to the high incidence of gait related eliminations reported.

The percentage of metabolic eliminations found are consistent with previous research (Nagy *et al.,* 2014). The primary reasons for a compromised metabolic status of an exercising endurance horse have been reported to be dehydration or exertional rhabdomyolysis (tying-up) (Fielding *et al.,* 2009). In the current study, the pacing strategy applied across loop 1 and specifically the higher percentage of loop 1 speed adopted during loop 2 completion compared to horses that finished influenced metabolic related eliminations. These horses then recorded a relatively slower final loop suggesting development of fatigue as a result of the pacing strategy used by their riders. Fatigue has multiple potential causal factors but is defined by a loss of force output in muscular tissue (Millet *et al.,* 2003), the failure of a specific physiological system (Green *et al.,* 1997), or in humans the psychological onset of a feeling of tiredness (Abiss and Laursen, 2005; Brooks *et al.*, 2000). The time-trial component of cycling events requires athletes to ride a predetermined distance in the shortest possible time requiring extreme physiological fitness, making pacing strategies essential to control fatigue (Abiss and Laursen, 2005).

Similarities exist between these events and equine endurance races, with successful horses in endurance completing races (set distances) in the fastest time possible without being eliminated (controlling fatigue and or avoiding injury). When horses are eliminated for either gait or metabolic reasons within endurance races this is as a result of only a brief clinical examination. As such, it is therefore at present unclear when horses are eliminated whether this is due to fatigue or injury/illness. However, despite the key to successful endurance racing being selection of the correct strategy, formal pacing strategies do not appear to be commonplace within endurance currently. Whilst the most common racing strategy in these 120 km races appears to be a slower loop 2 and 3 (compared with the first loop) followed by a final loop at a speed similar to or faster than loop 2, this may not be an optimal strategy. Further research to understand the impact of different pacing strategies on metabolic performance during races is warranted to promote strategies that can facilitate recovery at veterinary gates and minimise fatigue, thereby enhancing welfare and performance.

The current study represents a preliminary investigation into the effect of race strategy on the performance of CEI** horses covering 120 km in a single day. Whilst the results suggest pacing strategies are related to completion rates and elimination causes, it should be noted that only a relatively small number of horses (n=389) and races (n=24) were studied. Horses that did not complete had raced less distance than those than finished. The calculation of average speed and strategy percentages for each loop and the average speed for the race reflected the distance individual horses had completed to that point in time. Whilst this approach reflects the practice undertaken by the horse and rider combination in the race, it may also increase the potential for type I errors during analysis. Despite these potential limitations, the fact that significant differences were observed in race pace strategy between finishers and non-finishers does suggest that pacing strategy may have a strong effect on race performance. In addition, these races showed variation in competitive level and in the ability of horses competing, as evidenced by the large variation in speeds. Therefore, a more extensive study including a larger sample, across a broader range of competitive levels, covering a greater range of distances and encompassing multiple seasons of racing is required to confirm our findings.

Conclusion

A more variable and aggressive pacing strategy appears to be associated with an increased incidence of gait and metabolic elimination in FEI CEI** 120 km single day endurance races. Riders who adopt a more consistent pacing strategy throughout the race appear more likely to complete. Further research investigating the effect of pacing strategies on performance and equine welfare across all levels of endurance racing is warranted.

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