

Equine endurance race pacing strategy differs between finishers and non-finishers in 120 km single-day races

Marlin, David; Williams, Jane

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

3
4 David Marlin, Cambridge, UK dm@davidmarlin.co.uk

5 Jane Williams, University Centre Hartpury, Hartpury, Gloucestershire, UK

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9 Abstract

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17 majority of horses that did not finish were withdrawn for gait related reasons (n=125; 74%).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 Horses withdrawn at
22 the first veterinary check for “gait” recorded a 36% faster average speed than those withdrawn at the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 Horses withdrawn for “metabolic” reasons at the finish recorded a significant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

31 Word Count: 336

32 **Keywords:** competition; equestrian; completion; failure

33 **Introduction**

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

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

54 In the IAAF World Half-Marathon Championships, Hanley (2015) reported that the best performing
55 male and female athletes maintained their split speeds between 5 km and 15 km, whereas slower
56 athletes had decreased speeds from 5 km onwards. Hanley (2015) also observed that running in packs
57 resulted in smaller decreases in pace compared with athletes who ran alone after 5 km. Santos-Lozano
58 *et al.* (2014) studied a large number of participants in the New York City Marathon (2006-2011) and
59 reported lower variation in speed at 5 km splits in the top runners compared with runners who
60 completed at a slower overall speed. A strong feature of success in human endurance running appears
61 to be low variability in pace (Lambert *et al.* 2004; Ely *et al.* 2008; Haney & Mercer, 2011). Suggested
62 key factors in marathon failure are the selection of unsustainable initial running speeds and the role of
63 psychological factors leading to poor decision making by athletes (Renfree and St Clair Gibson,
64 2013).

65 The analysis of race strategy or pacing strategy is particularly well developed and studied in cycling,
66 in both shorter time trials (de Jong *et al.* 2015) and ultracycling events (Heidenfelder *et al.* 2016). One
67 particular advantage of cycling over running is the potential to measure power output in real time in

68 parallel with other variables such as performance and rating of perceived exertion, which may provide
69 further insight into pacing strategy (Konings *et al.* 2017).

70 The role of pacing strategy in equestrian sport has received little attention. Spence *et al.* (2012)
71 studied race data from 44,803 Thoroughbred racehorses in 3,357 races ranging in length from 1006 to
72 4225m (50.9-292.9 seconds duration) and observed that better performing horses exhibited race
73 length-dependent pacing strategies which were correlated with the fastest racing times.

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

81

82 **Methods & Materials**

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

103 subsequent loop completed relative to loop 1. This strategy marker was used to determine how riders
104 used speed strategically throughout the course of a race.

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

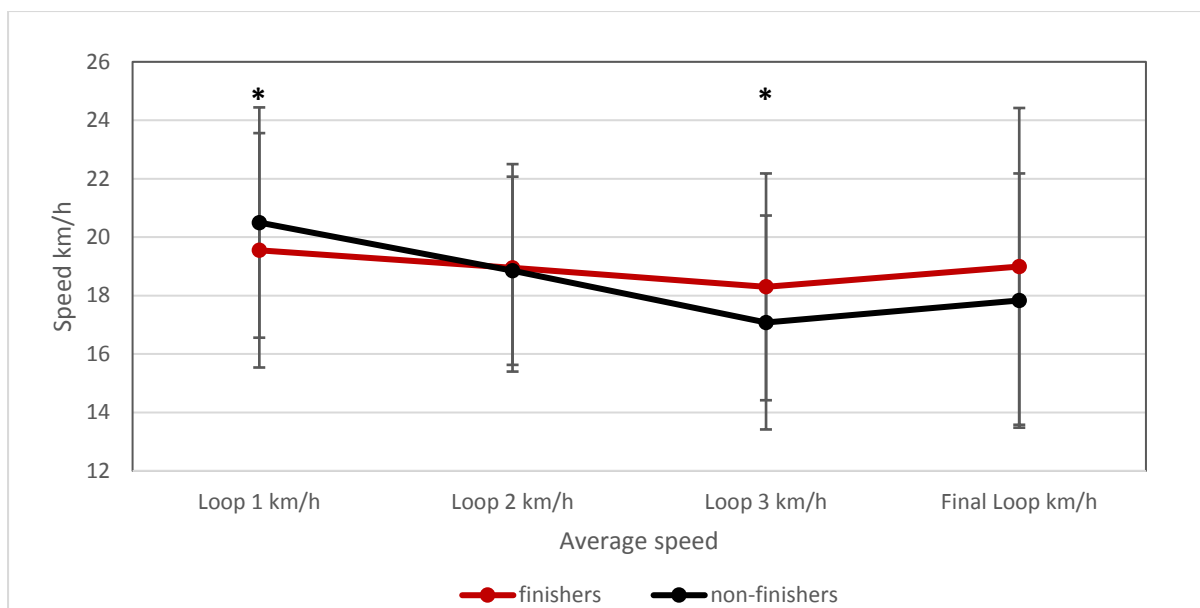
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114 **Results**

115 Competition records for 389 horses were evaluated; 56% (n=219) of horses successfully completed
116 the races surveyed, with the remaining 44% (n=170) not finishing. The mean number of starters was
117 18 ± 13 horses per race; records for horses which were not complete and for horses which were retired
118 by their rider were excluded prior to analysis (n=39). The majority of horses that did not finish, were
119 withdrawn for gait related reasons (n=125; 74%). Gait related withdrawals occurred at a relatively
120 consistent rate at veterinary checks at the conclusion of loops 1 (n=45; 36%), 2 (n=36, 29%) and 3
121 (n=35, 28%) but were lower at the final veterinary inspection at the finish (n=9; 7%). In contrast,
122 fewer horses were withdrawn for metabolic related reasons (n=46; 26%). The majority of withdrawals
123 occurred at the veterinary inspection for loop 3 of the race (n=32; 70%). No horses were withdrawn
124 on loop 1 for metabolic reasons, with the remaining 30% eliminated from the race after loop 2 (n=7;
125 15%) or the final veterinary inspection (n=7; 15%).

126 Race speed

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



137

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

141 Table 1: Race speed profiles for horses that did (finishers) and did not complete (non-finishers); km/h:
 142 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

143 ^a significant difference in speed within group; ^b significant difference in speed across groups

144

145 *Non-finishing horses: gait related reasons*

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

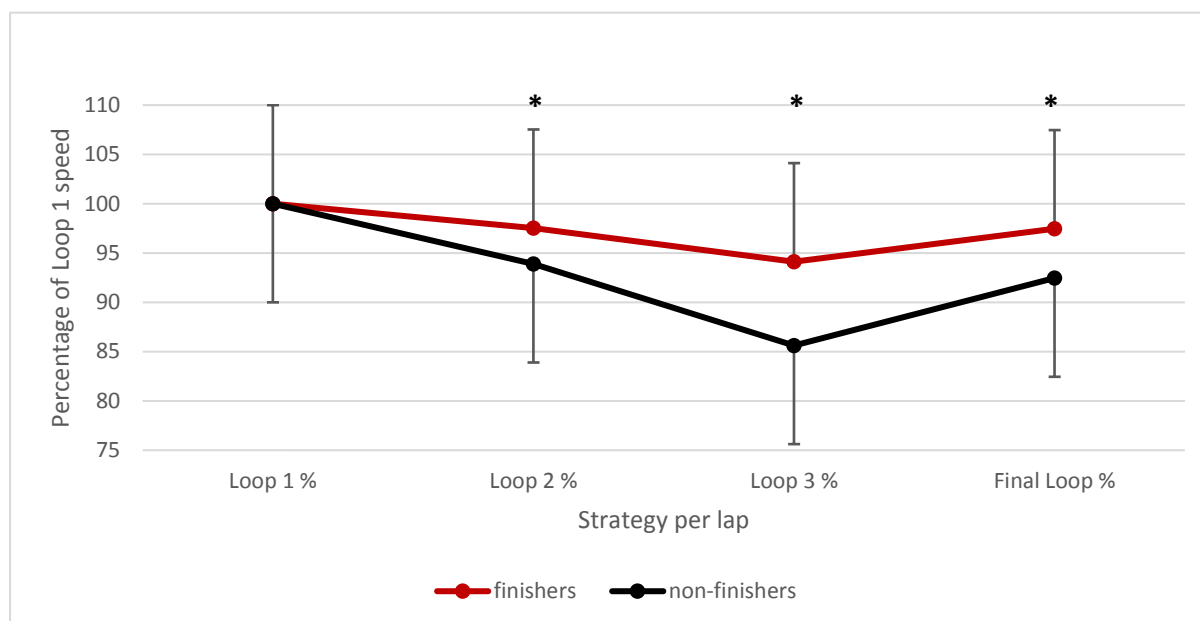
154 *Non-finishing horses: metabolic related reasons*

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

163 Race pattern

164 Horses that failed to finish races completed loop 1 at a faster speed than horses that finished (Figure
165 2). Non-finishers also displayed a reduction in speed across the remaining loops of the race (Table 2).
166 In contrast horses that finished had a slower loop 1 pace but went on to complete subsequent loops at
167 a higher percentage of their loop 1 speed (Table 2). These differences were found to be significant
168 between the groups for loop 2 ($P=0.002$; 4% increase compared to non-finishers), loop 3 ($P=0.0001$;
169 10% increase) and overall race strategy ($P=0.0001$; 5% increase), with horses that finished on average
170 maintaining a higher percentage of their loop 1 speed throughout the race, suggesting a more
171 successful pacing strategy.

172



173

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

177

178 *Non-finishing horses: gait related reasons*

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

185 *Non-finishing horses: metabolic related reasons*

186 No specific relationships between the strategic approach used and where horses were withdrawn for
 187 metabolic reasons was found ($P > 0.05$). However, the strategic approach adopted on loop 2 appears to
 188 be key for horses withdrawn from competition for metabolic reasons ($P = 0.02$). *Post hoc* analyses
 189 identified horses withdrawn at the 3rd veterinary check completed loop 2 at a 19% increase of loop 1
 190 speed compared to horses who withdrew at the end of the second loop ($P = 0.002$). Whilst horses
 191 withdrawn at the finish completed loop 2 with a 21% increase of loop 1 speed compared to horses
 192 who left the race after the second loop ($P = 0.01$). Interestingly, the average loop 1 speed of horses
 193 eliminated at the end of the second loop was not significantly higher than horses leaving the race at

194 the third and final veterinary checks (Table 1). This could suggest a lack of fitness may be related to
 195 early metabolic withdrawals.

196 Table 2: Race strategy profiles for horses that completed (finishers) and those that did not complete
 197 (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

198 ^a significant difference in speed within group; ^b significant difference in speed across groups

199

200 Discussion

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

209 Our results suggest that pacing strategies used by competitors in FEI CEI** 120 km single day races
 210 influence completion rates and therefore competitive success and risk of elimination. The use of
 211 inappropriate and highly variable pacing strategies have been associated with poor performance in
 212 human endurance running (Ely *et al.* 2008; Haney & Mercer, 2011; Renfree and St Clair Gibson,
 213 2013). Interestingly riders who adopted a more consistent pacing strategy were less likely to be
 214 eliminated for metabolic or lameness related problems. In particular, the speed selected to complete
 215 loop 1 of races was influential to non-completion. Faster loop 1 speeds was a significant risk factor

216 for subsequent for gait related elimination, therefore riders who selected unsustainable initial speeds
217 on loop 1 were more likely to not complete races. The overall race strategy combined specifically
218 with a consistent loop 2 pace appears key to preventing elimination for metabolic reasons.

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

242 Completion rates recorded here are lower than reported by Adamu *et al.*, (2014a; 74%) but similar to
243 Nagy *et al.*, (2014a; 51%). The number of horses eliminated for gait and metabolic related reasons is
244 also higher; the most comprehensive review of endurance racing to date reported 30% lameness
245 related and 9% metabolic related eliminations across 30741 FEI races in 47 countries (Nagy *et al.*,
246 2014). The differences observed here could be attributed to the specific level of competition analysed
247 combined with the race distance and variation in race terrain and speed (Adamu *et al.*, 2014b; Nagy *et al.*
248 *et al.*, 2014 a,b). Race location could also have been influential as 50% of races surveyed occurred in
249 Middle East locations, which Nagy *et al.* (2014a, b) reported increased the chance of horses being
250 eliminated due to either metabolic or lameness (gait) reasons.

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

262 The percentage of metabolic eliminations found are consistent with previous research (Nagy *et al.*,
263 2014). The primary reasons for a compromised metabolic status of an exercising endurance horse
264 have been reported to be dehydration or exertional rhabdomyolysis (tying-up) (Fielding *et al.*, 2009).
265 In the current study, the pacing strategy applied across loop 1 and specifically the higher percentage
266 of loop 1 speed adopted during loop 2 completion compared to horses that finished influenced
267 metabolic related eliminations. These horses then recorded a relatively slower final loop suggesting
268 development of fatigue as a result of the pacing strategy used by their riders. Fatigue has multiple
269 potential causal factors but is defined by a loss of force output in muscular tissue (Millet *et al.*, 2003),
270 the failure of a specific physiological system (Green *et al.*, 1997), or in humans the psychological
271 onset of a feeling of tiredness (Abiss and Laursen, 2005; Brooks *et al.*, 2000). The time-trial
272 component of cycling events requires athletes to ride a predetermined distance in the shortest possible
273 time requiring extreme physiological fitness, making pacing strategies essential to control fatigue
274 (Abiss and Laursen, 2005).

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

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

301

302 **Conclusion**

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

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